SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1955 Literature Review, Part I—Research Committee
Analytical Methods—Sewage—Radioactivity

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Second Progress Report

MAY, 1956—VOL. 28, No. 5

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OF THE

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IN CONJUNCTION WITH

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October 8-11, 1956

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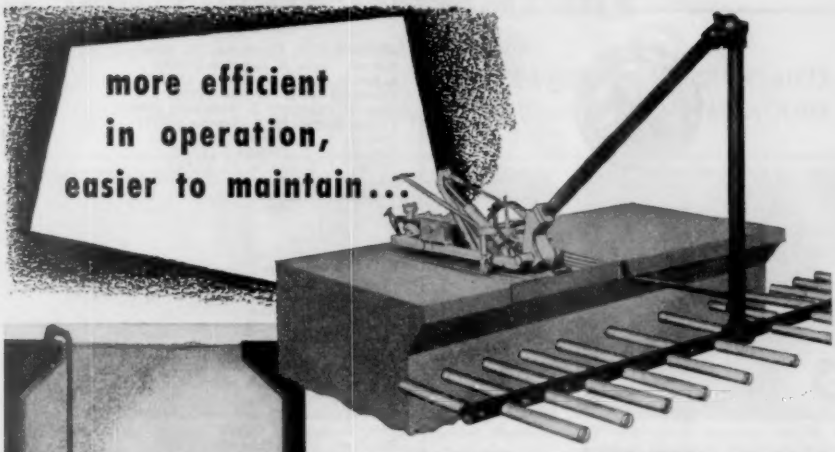

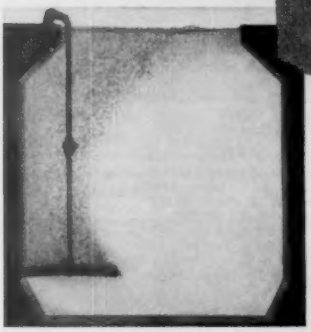

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4435 Wisconsin Ave., N.W., Washington 16, D. C. Send all manuscripts, advertising copy, subscriptions, address changes, etc., to this address.

SUBSCRIPTION RATES
Members of local sewage works associations affiliated with the Federation, $5.00 per year.

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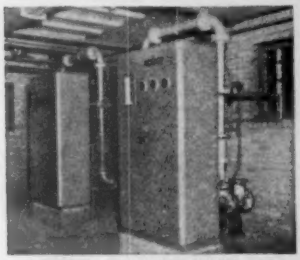

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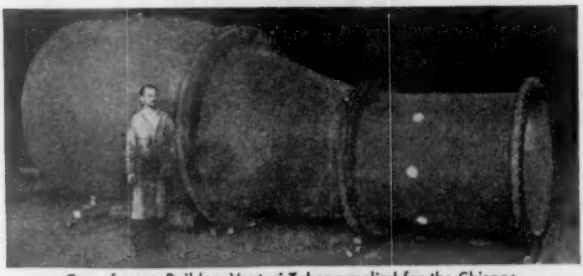

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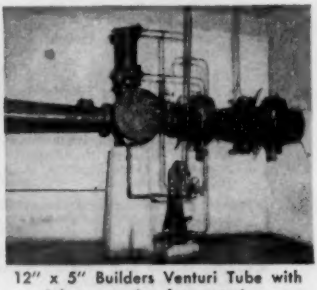

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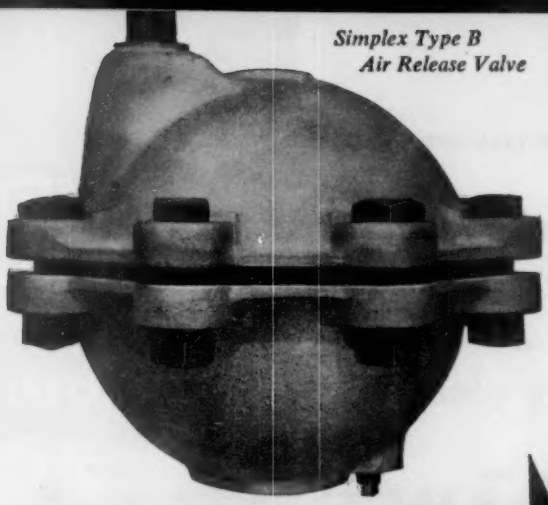

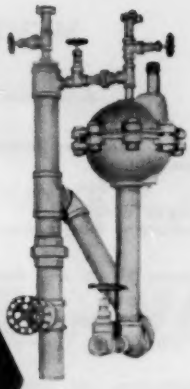

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Iowa Sewage and Industrial Wastes Assn.	P. M. Park Clear Lake, Iowa	Sept. 12–14, 1956
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Hotel Patten Chattanooga, Tenn.	Sept. 17–19, 1956
Georgia Water and Sewage Assn.	Hightower Textile Bldg. Georgia Inst. of Technology, Atlanta, Ga.	Sept. 19–21, 1956
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Canadian Institute on Sewage and Sanitation	Prince Edward Hotel Windsor, Ontario	Oct. 29–31, 1956

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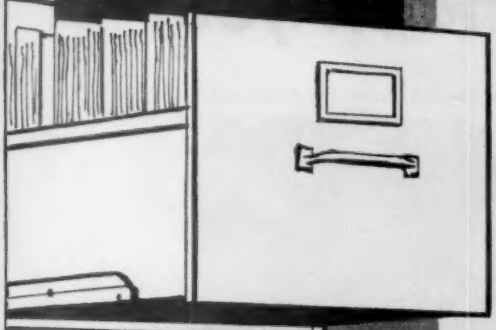

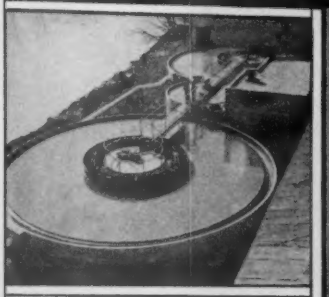

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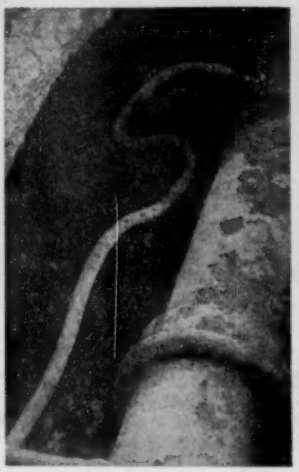

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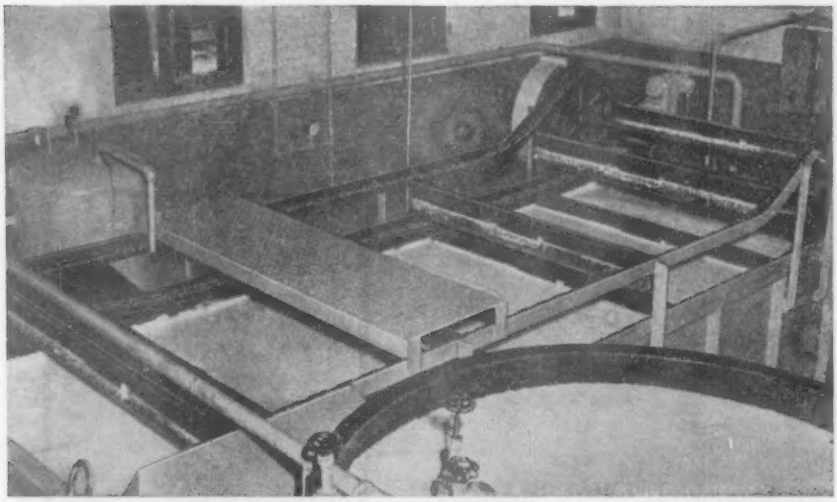

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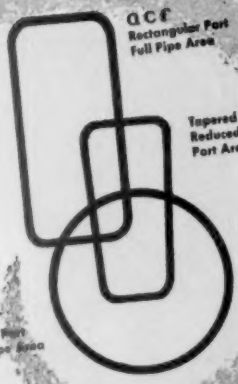

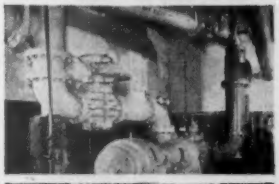

acf Plug Valves are backed up by Proof-of-Performance in every Processing Industry!

Turbulence! Loss of head pressure! These can present real problems when handling slurries and other viscous liquids! And because they are ordinarily the result of valves with "funnel action"...it pays you to make sure that the port opening has the same area as the pipe itself!

Pipe-matching port openings! This is only one of the reasons why more processing engineers than ever before are swinging over to acf Round Port Valves and Rectangular Port Valves. Other features, such as split-second, quarter-turn shut off...specially designed TEFLON* GASKET to prevent head leakage...all add up to lower maintenance costs and fewer work stoppages.

WRITE TODAY for descriptive Catalog E-8, W-K-M Manufacturing Company, Inc., P.O. Box 2117, Houston, Texas.

GET YOUR COPY of the acf Lube Manual, a complete description of lubricants and service recommendations. Ask for Manual No. 3.

*DuPont Tradename

acf
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PLUG VALVES
Now Manufactured by

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A SUBSIDIARY OF acf INDUSTRIES INCORPORATED
PLANT: MISSOURI CITY, TEXAS • MAILING ADDRESS: P. O. BOX 2117, HOUSTON, TEXAS

GENERAL CHEMICAL "ALUM"—*Preferred for Treatment of Industrial Wastes and Sewage*

America over, prevention of stream and lake pollution is a vital part of every program to conserve fish, wildfowl and recreational waterways. And, America over, industrial plants and municipalities cooperating in such programs rely on General Chemical Aluminum Sulfate to treat wastes and sewage. They find it economical, effective for coagulating and settling suspended matter, for reducing color and for making possible, clear, colorless effluents.

Prompt Shipment from Near-by Plants—As important as its efficiency, is the fact that General Chemical "Alum" is produced at 25 plants strategically located in every section of the nation. This means reliable service at all times . . . not only for your day-to-day operations but also when emergencies arise! That's why "G.C." Alum is preferred by so many municipal and industrial disposal plant operators from coast to coast. Make it your choice too!

FOR INDUSTRIAL WASTES AND SEWAGE

- Clean, easy to handle.
- Requires only low cost feeding apparatus, minimum attention.
- Clear, colorless effluents possible.
- Sludge digests readily.
- Economical.
- Dry feeds well, dissolves readily.
- Treated digested sludge dries quickly with minimum odor.
- Lower chlorine consumption results from reduced demand of clarified sewage.

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
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Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport Buffalo • Charlotte • Chicago • Cleveland • Denver • Detroit • Greenville (Miss.) • Houston • Jacksonville • Kalamazoo • Los Angeles • Milwaukee Minneapolis • New York • Philadelphia • Pittsburgh • Providence San Francisco • Seattle • St. Louis • Yakima (Wash.)

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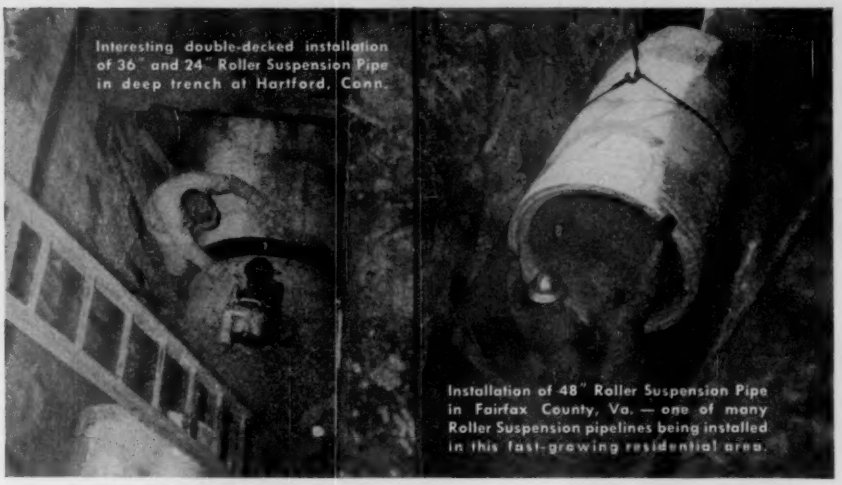
GC Allied Chemical

Basic Chemicals For American Industry

FOR EXCEPTIONAL STRENGTH
LOCK JOINT
ROLLER SUSPENSION PIPE



Interesting double-decked installation of 36" and 24" Roller Suspension Pipe in deep trench at Hartford, Conn.

Installation of 48" Roller Suspension Pipe in Fairfax County, Va. — one of many Roller Suspension pipelines being installed in this fast-growing residential area.

The unique manufacturing process by which Lock Joint Roller Suspension reinforced concrete sewer and culvert pipe is produced permits the use of a low water-cement ratio and a high proportion of stone in the mix. The concrete obtained by this system is unusually strong and resistant to abrasion.

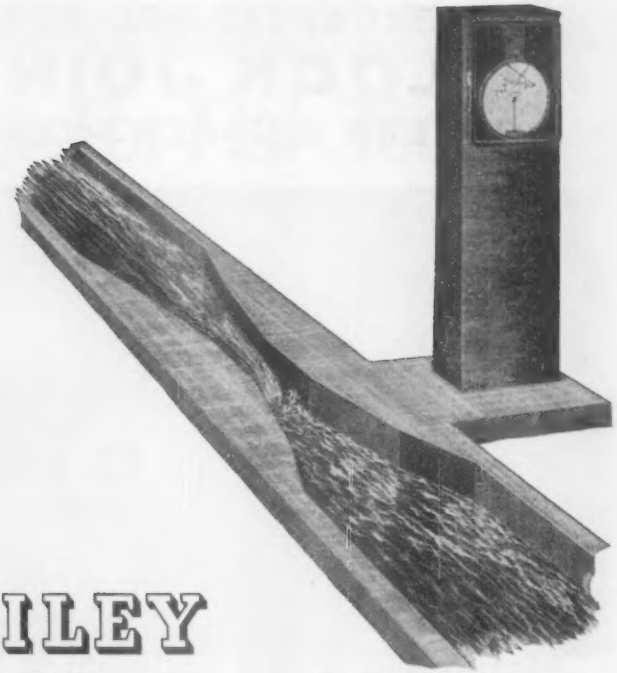
Roller Suspension Pipe of equal wall thickness and steel area to cast or machine made concrete pipe consequently offers a considerable premium in strength and durability.
For projects requiring exceptionally rugged sewer or culvert pipe, specify Lock Joint's ultra-modern ROLLER SUSPENSION PIPE.

LOCK JOINT PIPE CO.
East Orange, N. J.

Sewer and Culvert Pipe Plants:

Kenilworth, New Jersey	Valley Park, Missouri	Cheyenne, Wyoming
Hartford, Connecticut	N. Kansas City, Missouri	Casper, Wyoming
New Haven, Connecticut	Tulsa, Oklahoma	Tucumcari, New Mexico
Beloit, Wisconsin	Oklahoma City, Oklahoma	Hato Rey, Puerto Rico
Chicago, Illinois	Wichita, Kansas	Ponce, Puerto Rico
Rock Island, Illinois	Denver, Colorado	Caracas, Venezuela

Also Great Lakes Concrete Pipe Company with plants at Buffalo, N. Y. and Henrietta, N. Y.



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Open Channel Meters

for trouble-free low cost measurement of

Sewage, Industrial Wastes, Sludge, Irrigation, Water Supply

Bailey Meters offer these advantages—

1. Easy to Install and Maintain
2. Retain Accuracy
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5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls
8. Low Cost

For further information on how Bailey Meters can meet your needs, ask for Bulletin M22-5.

MU25

Bailey Meter Company

1066 Ivanhoe Road • Cleveland 10, Ohio

Meters and Controls for Sewage and Water

Venturi Tubes • Flumes • Weirs • Nozzles • Orifices • Direct Mechanical and Remotely Located Registers • Air-Operated, Electronic and Electric Controls

For sanitary or storm sewers

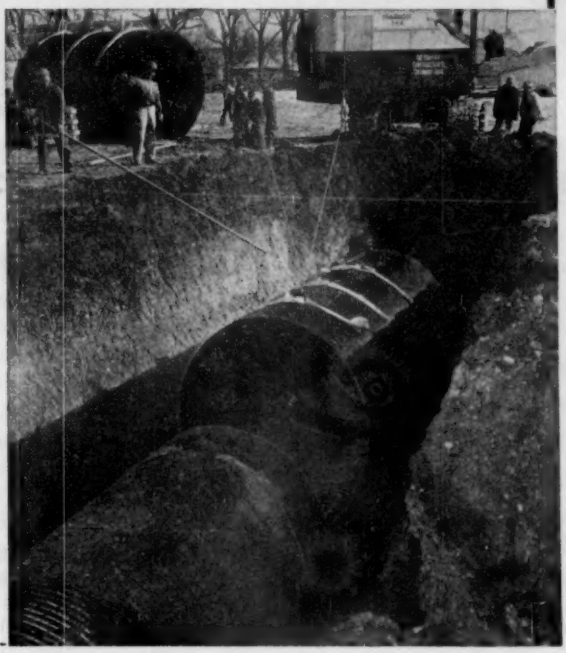
Only With an Armco Structure can you get

• Top Structural Strength • Top Material Durability • Top Flow Capacity

Armco Corrugated Metal Sewers offer advantages unmatched by any other type of sewer structure. Want proof? Check the following four statements. *Only* an Armco Sewer gives you the choice of all these advantages in a single structure. And you can specify the strength and durability *required* by your application.

- ☑ Flexible corrugated metal strength to withstand the impact of live loads without cracking or breaking.
- ☑ Choice of coatings to meet corrosive conditions, plus a thick pavement to combat erosion if required.
- ☑ A smooth interior to provide utmost flow capacity when required.
- ☑ Strong, tight joints that eliminate possibility of disjointing, infiltration or failure as an integral conduit.

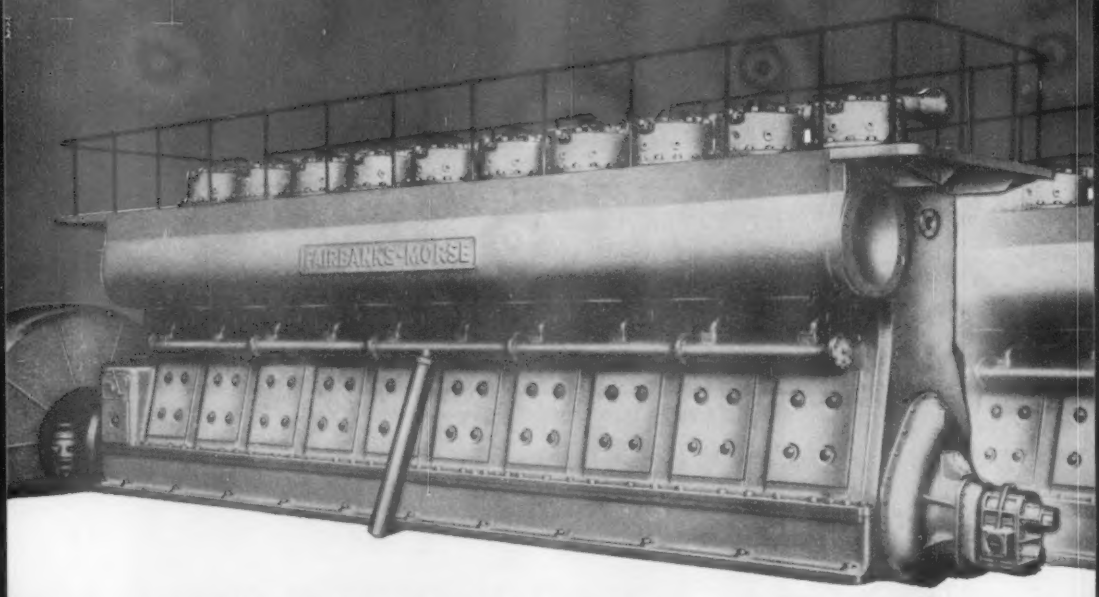
For data, just write us about your sewer problem. We'll also give you recommendations, if you wish. Armco Drainage & Metal Products, Inc., 4866 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.



ARMCO
SEWER
STRUCTURES

ARMCO®

Fairbanks-Morse tops REA



Record 43,300 Hp. Performance

In the top four plants of the national REA competition, there is more than two and a half times as much Fairbanks-Morse horsepower as in all other engines combined—a total of 43,300 horsepower.

Never before has there been such a clear-cut record of efficiency, on such a broad base, in favor of any engine in this competition.

Look at some of the figures:

- First, F-M horsepower produced more than 2/3 of the total power generated by the top four winning plants.
- Three 3500 horsepower Model 31A's generated 82% of the power in the top award-winning Johnson plant.
- Two exclusive F-M powered plants placed second and fourth with only a spread of .1 mill between them.
- One Model 31 in the Top Plant carried the highest penalty of longest operation on straight oil—yet efficiency was higher than plant average.

Here, in engine after engine, is a record of operating standards of efficiency unequaled by any other engine in such numbers.

You Can't Make a Better Power Buy Than a Fairbanks-Morse Diesel or Dual Fuel Engine

FAIRBANKS-MORSE

a name worth remembering when you want the best

DIESEL AND DUAL FUEL ENGINES • DIESEL LOCOMOTIVES • RAIL CARS • ELECTRICAL MACHINERY • PUMPS • SCALES
HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS

mass efficiency competition

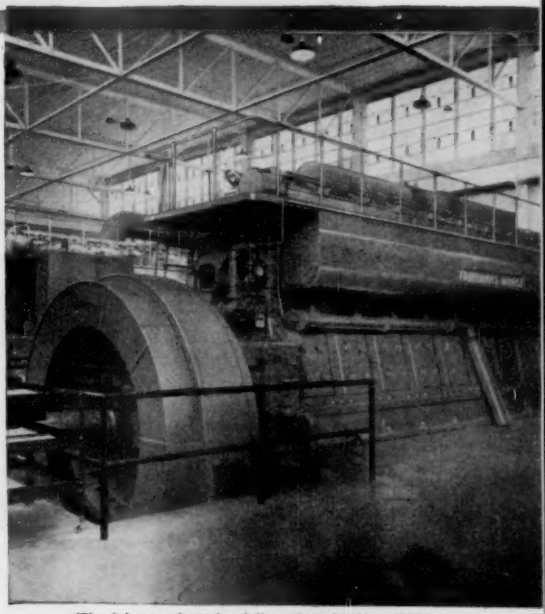
Outstanding Single Engine Performance

Engine No. 6 is one of three Fairbanks-Morse Model 31A 3500 horsepower engines that have helped keep the Johnson plant tops in efficiency for four years*. In winning previously, this engine set a record of 9213 BTU per kw-h—still unsurpassed by any engine today.

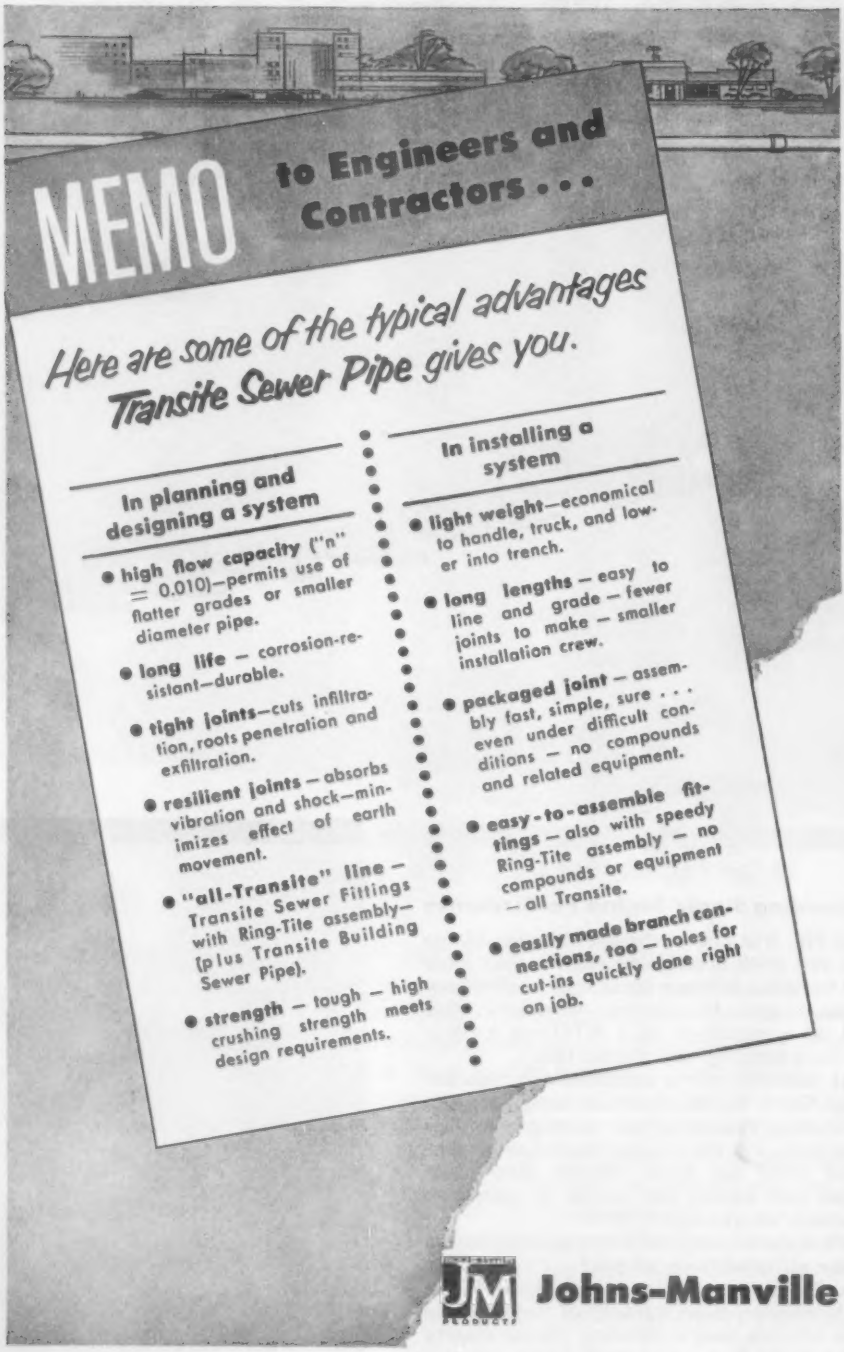
That winning record automatically selected the big No. 6 for the heaviest assignment to straight oil operation this year when gas supplies became short. *Yet*, the engine achieved an average of 9642 BTU per kw-h (Better than plant average) and during one period of operation maintained, an average of 8652.

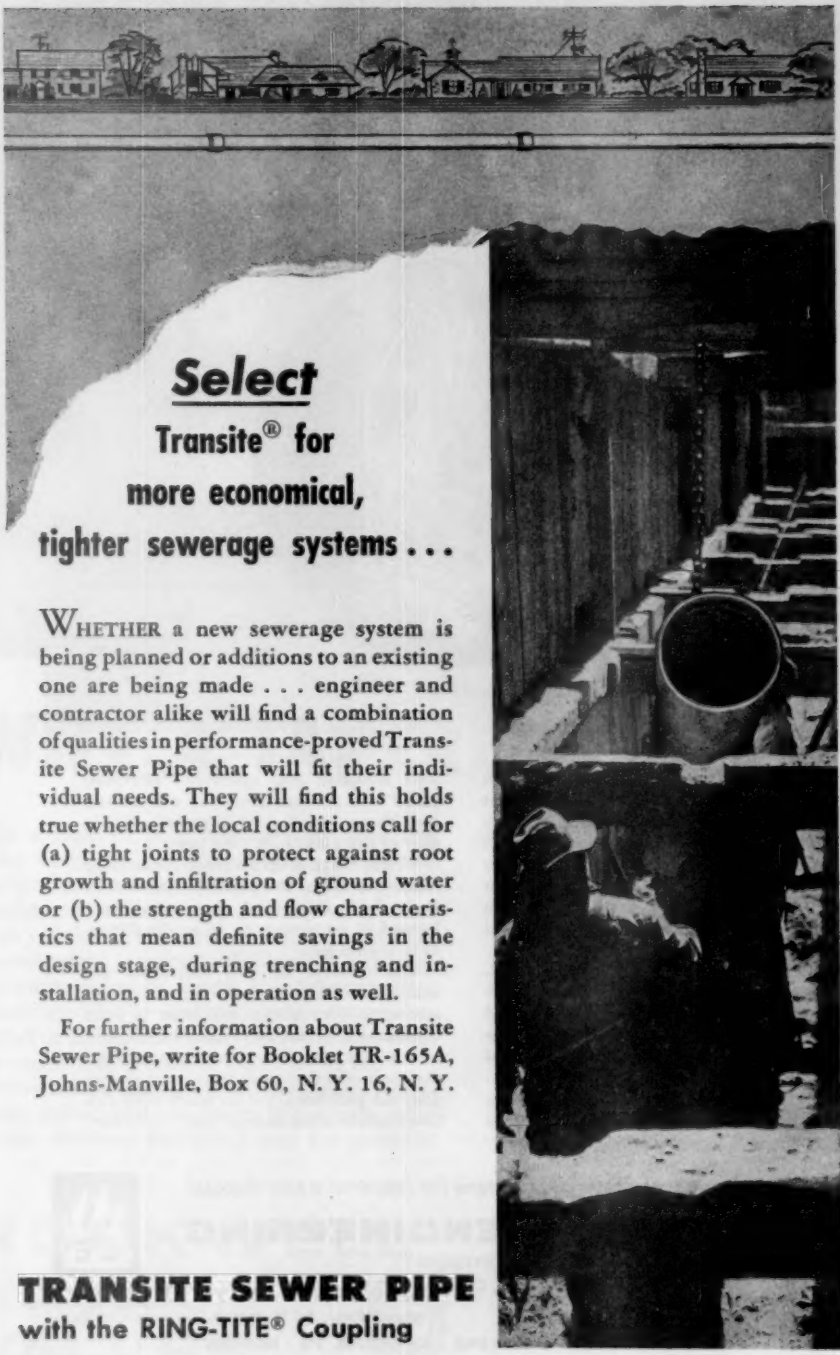
That's approximately 40% thermal efficiency!

Under all conditions of load . . . penalties of straight oil operation . . . two high-altitude plant locations—close scrutiny of performance records of this year's winning plants clearly establishes the fact—you can't make a better buy than a Fairbanks-Morse Diesel or Dual Fuel Engine. Fairbanks, Morse & Co., Chicago 5, Ill.



*The Johnson plant also delivered top kw-h per BTU last year, but was eliminated from competition due to winning in two previous years


MEMO
to Engineers and Contractors . . .
Here are some of the typical advantages Transite Sewer Pipe gives you.
In planning and designing a system
● high flow capacity ("n" = 0.010)—permits use of flatter grades or smaller diameter pipe.
● long life — corrosion-resistant—durable.
● tight joints—cuts infiltration, roots penetration and exfiltration.
● resilient joints — absorbs vibration and shock—minimizes effect of earth movement.
● "all-Transite" line — Transite Sewer Fittings with Ring-Tite assembly—(plus Transite Building Sewer Pipe).
● strength — tough — high crushing strength meets design requirements.
In installing a system
● light weight—economical to handle, truck, and lower into trench.
● long lengths — easy to line and grade — fewer joints to make — smaller installation crew.
● packaged joint — assembly fast, simple, sure . . . even under difficult conditions — no compounds and related equipment.
● easy-to-assemble fittings — also with speedy Ring-Tite assembly — no compounds or equipment — all Transite.
● easily made branch connections, too — holes for cut-ins quickly done right on job.
JM PRODUCTS
Johns-Manville



Select

Transite® for more economical, tighter sewerage systems . . .

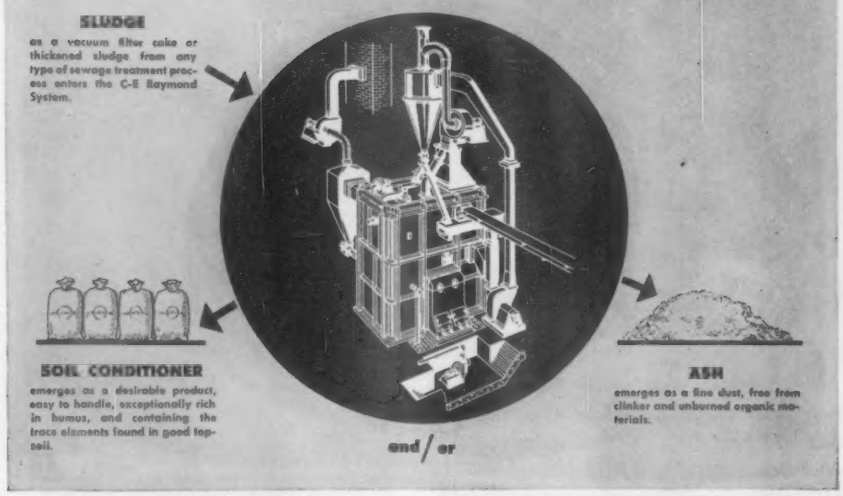
WHETHER a new sewerage system is being planned or additions to an existing one are being made . . . engineer and contractor alike will find a combination of qualities in performance-proved Transite Sewer Pipe that will fit their individual needs. They will find this holds true whether the local conditions call for (a) tight joints to protect against root growth and infiltration of ground water or (b) the strength and flow characteristics that mean definite savings in the design stage, during trenching and installation, and in operation as well.

For further information about Transite Sewer Pipe, write for Booklet TR-165A, Johns-Manville, Box 60, N. Y. 16, N. Y.

TRANSITE SEWER PIPE
with the RING-TITE® Coupling

The C-E Raymond System —

the MODERN method of SLUDGE DISPOSAL


SLUDGE
as a vacuum filter cake or thickened sludge from any type of sewage treatment process enters the C-E Raymond System.
SOIL CONDITIONER
emerges as a desirable product, easy to handle, exceptionally rich in humus, and containing the trace elements found in good topsoil.
and / or
ASH
emerges as a fine dust, free from clinker and unburned organic materials.

The C-E Raymond System is the most popular . . . most versatile on the market today. It combines the principles of Flash Drying and Incineration in a single compact system that allows you to Flash Dry or Incinerate sewage sludge alternately or concurrently. It is available with a high temperature deodorization system that assures odor-free operation.

Flash Drying by the C-E Raymond System is a continuous process in which vacuum filtered sludge — if uncontaminated with undesirable industrial wastes — is efficiently heat dried to a marketable soil conditioner retaining all its original nitrogen, but eliminating the objectionable qualities of the original wet sludge. In a well designed and operated "activated plant" the revenue from the sale of soil conditioner is sufficient to cover a sizable part of the plant operating costs.

Where the production of soil conditioner is not desired or the sludge is unsuitable, it is flash dried and then completely burned in suspension to an easily disposable, sterile ash.

The services of C-E specialists are available to help you plan for the end of atmospheric or stream pollution in your community, as has been done in so many others. For specific recommendations on the most practical answer to your sludge disposal problems, get in touch with the Combustion office nearest you. B-860A

also flash drying and incineration systems for industrial waste disposal

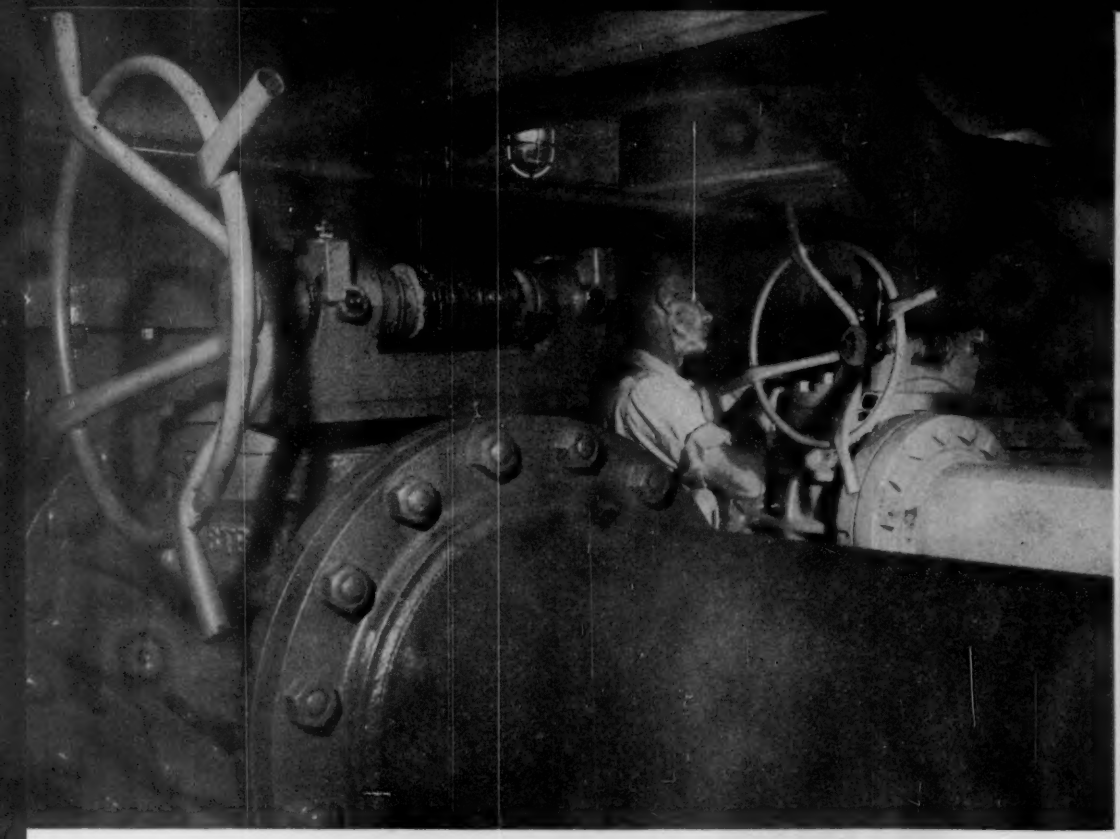
COMBUSTION ENGINEERING

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y. *Western Office:* 510 W. Sixth St., Los Angeles 14, Calif.

CANADA: COMBUSTION ENGINEERING — SUPERHEATER, LTD., MONTREAL



WHY A TAPERED PLUG?

Only a tapered plug *adjusts itself* into the valve body for perfect seating . . . yet is easily freed for operation. In Rockwell-Nordstrom valves, the tapered plug is even more efficient because it is seated on a film of pressurized lubricant. Acting like a spring, lubricant pressure keeps the tapered plug "cushioned" for instant, easy operation. Galled or stuck valves are prevented on even the most difficult waste plant services.

Pressurized lubricant in Rockwell-Nordstrom valves has two more important jobs. It also forms a leakproof seal for positive shut-off on heaviest sludge or light gases. And by eliminating the wear of metal-to-metal abrasion, lubrication saves maintenance and repair costs.

Rockwell-Nordstrom valves come in sizes to 16" and WOG ratings to 200 lb. for every waste plant need. They save money, improve performance everywhere you use them, yet Rockwell-Nordstrom valves cost no more than ordinary valves. Send the coupon for complete information. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Canadian Valve Licensee: Peacock Brothers Limited

ROCKWELL-
Nordstrom
VALVES

Lubricant Sealed For Positive Shut-Off

40th YEAR *of lubricated plug valve leadership*

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Rockwell Manufacturing Company
Pittsburgh 8, Pennsylvania

☐ Please send me Bulletin C-5200.
☐ Please have your sales engineer call.

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Unique method of placing concrete saves time and money

The concrete for six 100-ft. diameter settling tanks at the Grand Rapids sewage plant was placed by the special swivel pump rig shown at the left. This method saved considerable time, labor and money.

Concrete was pumped through the rotating conduit and deposited continuously in the forms. Each tank required 180 cu. yd. of concrete and was completed in a seven-hour day by a seven-man crew.

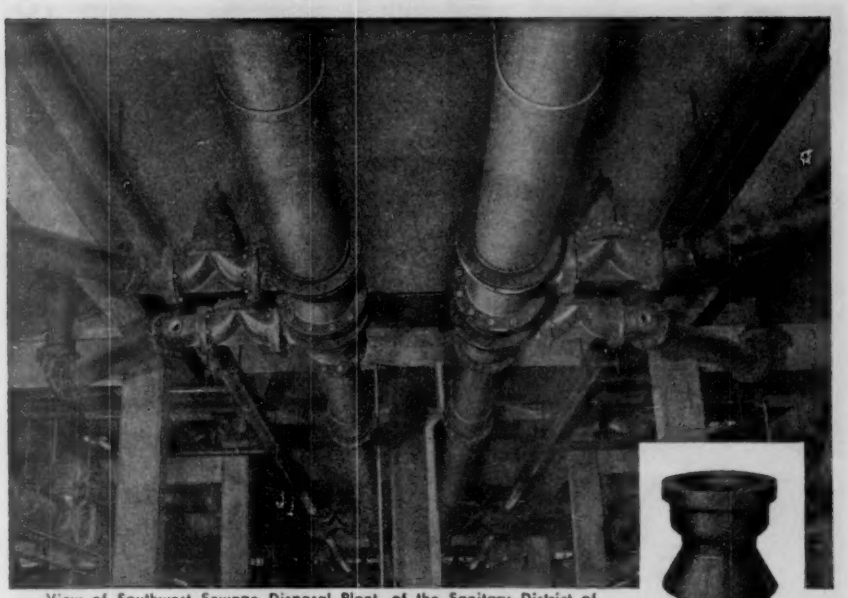
This demonstrates concrete's adaptability to the special conditions of any job. Placed by this or another method, concrete is the ideal material for sewage treatment plants and facilities.

Concrete is moderate in first cost. It requires little or no maintenance. It has extremely long life. The result is ***low-annual-cost*** service.

For more information on concrete for sewage treatment plants write for a free illustrated booklet, *"Sewage Treatment Works,"* distributed only in the United States and Canada. Address Dept. 5-76.

PORTLAND CEMENT ASSOCIATION, 33 W. Grand Ave., Chicago 10, Ill.

A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

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201-299 North Talman Avenue • Chicago 80, Illinois

Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
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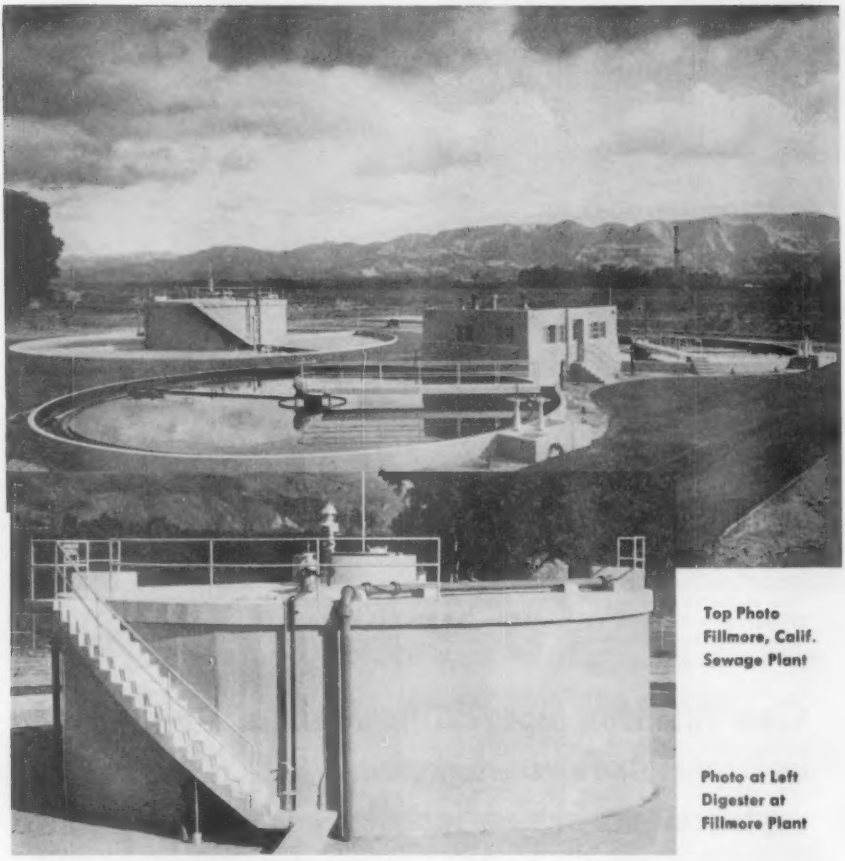

Top Photo
Fillmore, Calif.
Sewage Plant

Photo at Left
Digester at
Fillmore Plant

Varec Equipment helps Fillmore, Calif. meet its Sewage Problem

Fillmore faced a common problem of many Southern California cities, — a booming population that over-taxed the sewage system.

The solution was a compact, modern digester system that is efficient and attractive. To protect this fine plant against fire and explosion, and regulate the volatile sewage gas for smooth operation, VAREC SEWAGE GAS CONTROL AND SAFETY DEVICES are on the job.

Over 18 years of experience in controlling sewage gases has made Varec one of the leaders in the field.

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THE VAPOR RECOVERY SYSTEMS COMPANY
2820 N. Alameda St., Compton, California
Cable Address: Varec Compton California (U. S. A.) All Codes

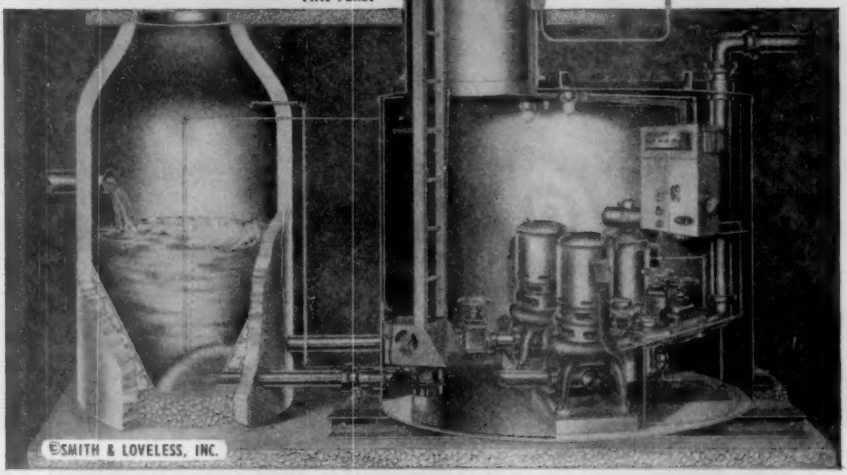
S-14 Available from Authorized Sewage Equipment Agents throughout the U.S. and Canada

HUNDREDS OF INSTALLATIONS—IN 27 STATES!

Smith & Loveless FACTORY-BUILT PUMPING STATION

PROVEN QUALITY— WITH FACTORY-BUILT SAVINGS

PAT. PEND.



We specialize in building America's finest sewage lift stations. Acceptance proves their quality. Smith & Loveless offer you a complete line of six standard size lift stations with capacities from 20 GPM to 1600 GPM per pump or ejector. Larger capacity stations are built to your order.

- An integrated design, each piece proven by the test of time.
- Precision assembled by factory experts.
- Automatic dehumidifier to eliminate condensation.
- A central electrical control cabinet prewired and color coded.
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- Factory tested and adjusted by actual operation before shipment.
- Easily and quickly installed.
- Especially designed for minimum maintenance.

For Job Recommendations, complete specifications, and drawings — all part of the latest edition of the 100 page Smith & Loveless lift station Data Manual . . .

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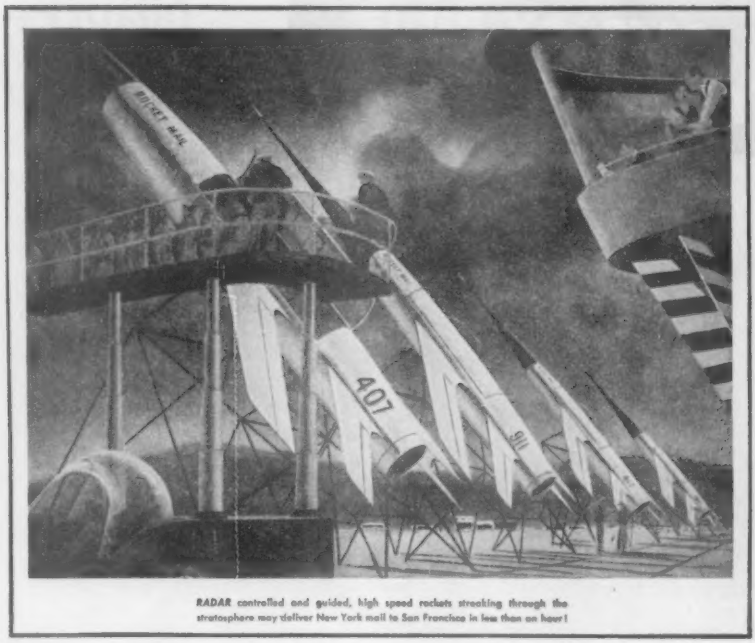
Manufacturing Plant • Merriam, Kansas

REPRESENTATIVES IN PRINCIPAL CITIES



RADAR controlled and guided, high speed rockets streaking through the stratosphere may deliver New York mail to San Francisco in less than an hour!

100 years from now...

WE MAY SEND MAIL BY ROCKET!

A century from now a wonderful, exciting and different world. But there will be one familiar note. The cast iron pipe laid today will still be carrying water and gas to the homes and industries of tomorrow.

In over 60 American cities, these dependable cast iron water and gas mains, laid more than a century ago, are still serving efficiently. And modernized cast iron pipe, centrifugally cast, is even stronger, tougher, more durable.

U. S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.

U.S. cast iron PIPE

FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

CAST IRON

U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham 2, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.

Comminutor installation serves 7 years with only routine maintenance

In Madison-Chatham Sewage Treatment Plant, money saved by low installation and maintenance costs helps pay for Worthington comminutor and other public works.

"Since 1948, when our Worthington comminutor was installed, it has operated successfully with only routine maintenance. The comminutor's reliability has proved a real blessing for our plant operation."

So says Ed Molitor, Plant Superintendent, about the 25-inch comminutor in service at Madison-Chatham, N. J., Joint-Meeting Sewage Treatment Plant.

Mr. Molitor isn't alone in his opinion of the rugged Worthington comminutor. We've had similar reports wherever they're used—and that covers the country.

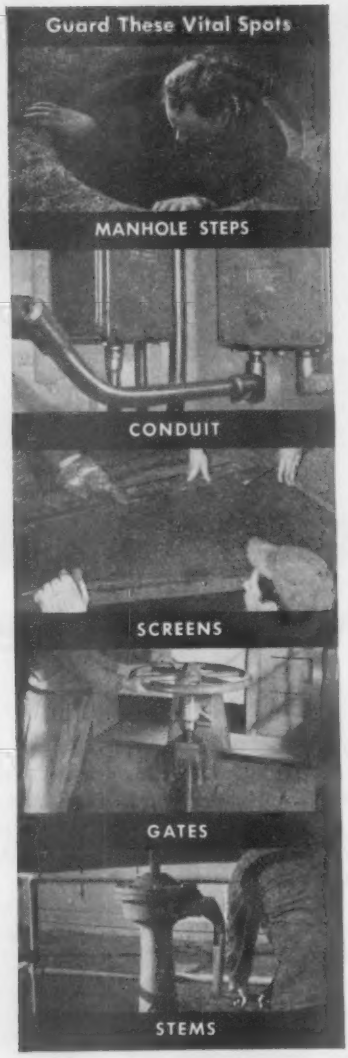
Learn about all the advantages of the Worthington comminutor. Contact your nearest Worthington District Office or write today for Comminutor Engineering Manual, W-317-B17, Worthington Corporation, A&SP-Public Works, Harrison, N. J.

WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

WATER WORKS PUMPS • SEWAGE PUMPS • COMMINUTORS • VERTICAL TURBINE PUMPS • VACUUM PUMPS

Proved Protection against Corrosion with EVERDUR



EVERDUR* RESISTS CORROSION. Installations of Everdur sewage treatment and waterworks equipment in the United States have been in service without replacement for 20 years and longer — evidence of Everdur's ability to resist corrosion common to these operations.

EVERDUR IS TOUGH. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion — so that wrought equipment can be designed with lighter weight.

EVERDUR IS READILY FABRICATED. Everdur alloys are available for hot or cold working, welding, free-machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment"—or for assistance of the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off. 56129

EVERDUR

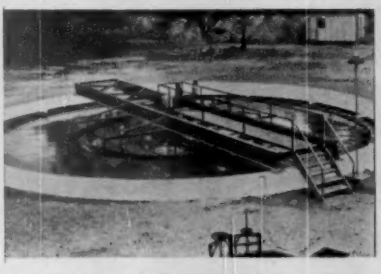
ANACONDA®

COPPER-SILICON ALLOYS

STRONG • WELDABLE • WORKABLE • CORROSION-RESISTANT

YEOMANS MANUFACTURES THE MOST COMPLETE LINE OF APPLICATION-DESIGNED SEWAGE TREATMENT EQUIPMENT

which includes . .



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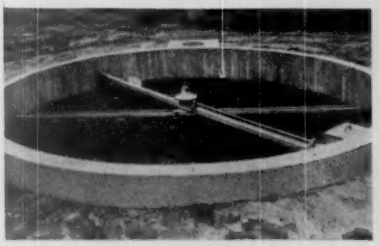
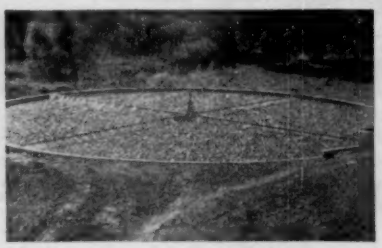


. . the **WATER-WHEEL,** a rotary distributor used with trickling filter systems in the secondary treatment of sewage. An exceptionally rugged, yet simple piece of equipment, the Water-wheel provides uniform distribution over the entire filter bed at all flow rates . . even the lowest. Costly accessories such as underground feed pipe, dosing chamber with siphon, center support, and mercury seal are not required.



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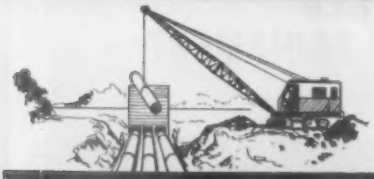
How Oklahoma City Solved a Sewer Relocation Problem –



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Mechanical Joint Pipe

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In addition to planning for adequate capacity, these officials planned for longer and more economical service. Corrosion-resistant, longer lasting cast iron pipe was their choice . . . *quality* pipe, centrifugally cast by the American Cast Iron Pipe Company.

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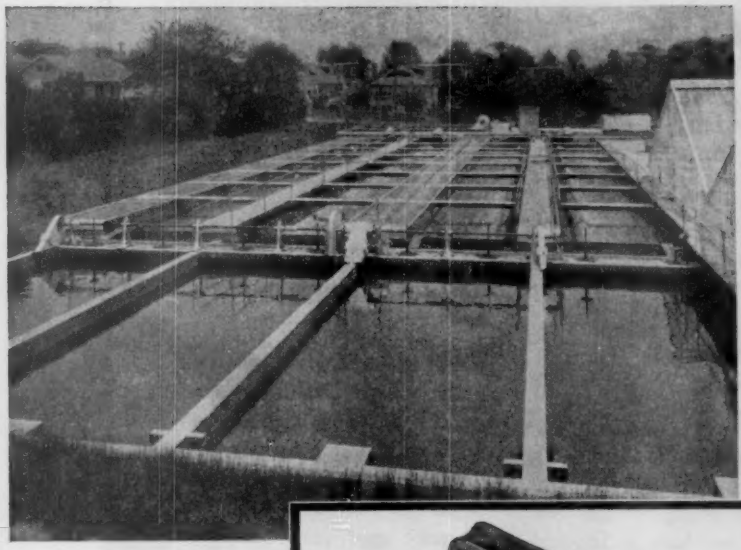
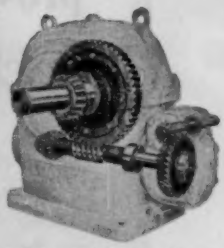


FOR 15 YEARS, the Link-Belt chain on final tank Straightline Collectors at this Collingswood (N.J.) activated sludge plant rendered dependable service, running 24 hours per day, *without replacement.* Straightline collectors in primary tanks have been in service for 24 years without replacement. Clearness of effluent may be judged by reflection of the drive machinery in final tanks in foreground.



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Link-Belt offers you a broad line of *quality* sanitary equipment — including screens, collectors, mixers and complete conveying and power transmission equipment. In fact, Link-Belt pioneered such life-lengthening features as Flint-Rim sprockets and Promal chain.

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Here's how an "*accident*" proved the ruggedness of the Fischer & Porter Chlorinator

Here's the true story of how one user decided the modern, rugged Fischer & Porter Chlorinator was his best buy.

"I was impressed with the F&P Chlorinator the minute your field engineer arrived."

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And what's more, this is only one true story of user satisfaction with the F&P Chlorinator. Everywhere users are adding their words of praise for this chlorinator.

In addition to the ruggedness of the unit, you get simplified operation, the absolute minimum of maintenance costs. As one user puts it, "We shudder at the thought of overhauling other chlorinator units, but it's a pleasure to bring the F&P unit into the shop. We know it will need very little maintenance work—and any work it does need will be 'child's play,' compared to the time and back-breaking labor spent on other chlorinators."

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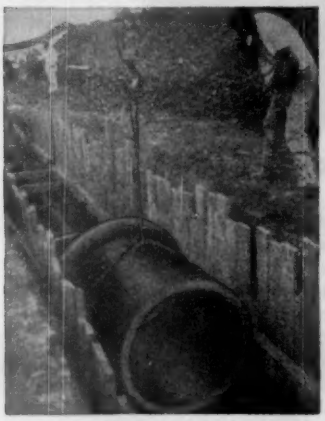

FOR VAN NUYS, CALIF.—City Engineer, Lloyd Aldrich of Los Angeles. CONTRACTORS—Boske and Broderich.

Replacement jobs like this prove that you *always* save money by installing Clay Pipe first. It can't be eaten away by any of the acids and chemicals found in residential or industrial wastes. Its cost per year of service is the lowest. And the new jointing techniques developed through Clay Pipe research result in tight, infiltration-proof lines that cut costs at the treatment plant. Why take chances on substitutes? Use Vitrified Clay Pipe . . . and be sure the job is down to stay.

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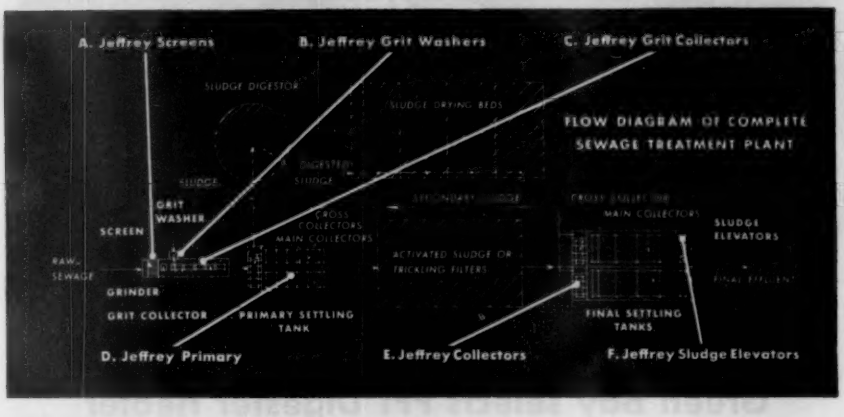

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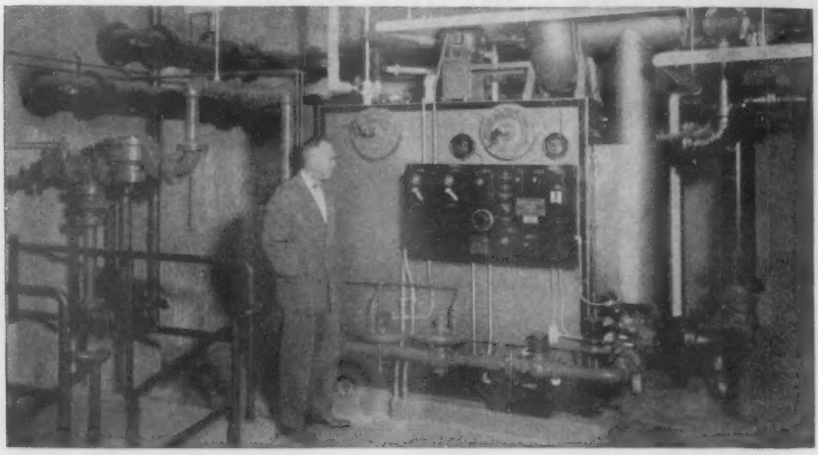
G. W. Martin, Green Bay's Supt. of Sewage Treatment, checks new PFT Heater & Heat Exchanger

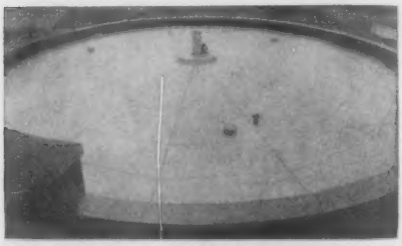


Green Bay selects PFT Digester Heater for operating economy, close control

In expanding its digesting operation, Green Bay, Wisconsin, once again chose PFT equipment for modern *controlled* digestion. In 1936, PFT had supplied the primary treatment plant with two Floating Covers for its 40′ digesters.

Key feature of the newly expanded plant is the PFT Heater & Heat Exchanger (750,000 B.t.u. per hr.). Located in the adjacent Control Chamber with all parts accessible, this compact unit heats sludge *externally* with no piping or equipment required inside the digesters.

Temperature of the sludge is maintained at optimum range by recirculating raw sludge or digestion tank contents (or a mixture of both) through the unit.



PFT Spirally Guided Gas Holder in Green Bay's 85′ digester. Unit has a gas storage of 28,000 cu. ft.; can be held under operating pressure of 6″ of water col.

By heating sludge *outside* the digester, the unit eliminates many maintenance problems. Unlike the system in which coils are located in the digestion tank, the PFT Heater can be cleaned without interrupting the digester operation. All parts of the unit are readily accessible—return bends and sludge tubes are held in place by gasketed joints so that cleaning and adjustments require less time and effort.

The PFT Heater provides operational economy by utilizing all sludge gas produced in the digester. Fired by gas *or* oil, the unit is switched to oil only when the gas supply is low, thereby cutting digester fuel costs substantially.

Additional PFT equipment recently installed at Green Bay includes a *Spirally Guided Gas Holder* (see illustration) and a complete Gas Safety System for maximum protection against fires and explosions.

Design of plant by / *Jerry Donohue Engineering Company Sheboygan, Wis.*

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 28 **May, 1956** **Number 5**

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Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
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There's a D-O UNIT for Practically Every Step in Every Sewage Treatment Flowsheet

Aerial view of the El Paso plant with the two Monorake units shown at top right. Consulting Engineers: Ashley G. Classen & Associates, El Paso, Texas

EL PASO TEXAS

Adds Secondary Treatment to Sewage Plant . . . Biofiltration Flowsheet Used

El Paso, rapidly growing Texas city, recently added secondary treatment to its sewage plant employing four Dorrco Distributors followed by two Monorake mechanisms.

The two Monorake units are each installed in a basin 67 ft. 10½" wide by 245 ft. long. The Distributors, among the largest ever manufactured, are 220 ft. in diameter each capable of handling a maximum flow of 13,900 gpm at 2.75 ft. head.

If you would like more information on the complete line of Dorr-Oliver sewage treatment equipment write to Dorr-Oliver Incorporated, Stamford, Connecticut for Bulletin No. 6041.

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1955 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1955 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, H. E. Orford, *Vice-Chairman*, H. Amberg, B. Berger, D. E. Bloodgood, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, T. deS Furman, I. Gellman, A. S. Goldin, A. E. Griffin, C. Henderson, A. Hirsch, R. D. Hoak, R. S. Ingols, P. W. Kabler, M. Katz, R. P. Logan, R. Manganelli, P. H. McGauhey, W. A. Moore, G. Paine, R. C. Palange, C. M. Palmer, G. A. Rohlich, L. R. Setter, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, J. W. Wiseman and R. L. Woodward.

Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This first of two sections of the review deals with analytical methods, sewage and radioactivity. The second section, dealing with industrial wastes and water pollution, will be published in the June, 1956 issue of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

Gellman and Heukelekian (14) investigated the effect of various types of seeding materials in the determination of the B.O.D. of various industrial wastes and lower aliphatic alcohols by the standard dilution method. These seeding materials, in order of their decreasing activity, were:

1. Acclimated activated sludge.
2. Mixed dispersed growth.
3. Settled dispersed growth.
4. Normal activated sludge.
5. Normal sewage seed.

This order of effectiveness was not altered in their study of rag, jute, sulfite pulp cooking wastes, spent yeast nutrient, washings from the manufacture of chewing gum, methanol, ethanol, isopropanol, butanol and mixtures of these alcohols. Gum washings and isopropanol were the most resistant to oxidation and the sulfite pulp waste the least resistant. The oxidation rates of these various wastes and alcohols were measured by use of the Warburg apparatus. From the results obtained, the authors advocate the wider use of acclimated activated sludge as a seeding material.

Mills and Stack (31) found that the formally assumed constant oxidation rate of domestic sewage did not hold true for many industrial wastes. Their study supported the results by others

that the lag period of oxidation can be reduced by the use of an acclimated seed. However, some non-toxic chemicals remained resistant even after 100 days of aeration. Instead of the usual 5-day B.O.D., long term B.O.D. studies are considered necessary in evaluating the effect of a given seed on a given chemical, as follows:

1. Determine a long-term B.O.D. using an unacclimated seed.
2. If an unacclimated seed is unsatisfactory, then the seed is acclimated until a satisfactory one is obtained. If such a seed is not obtained within 100 days, the material is assumed to be unoxidizable.
3. The long-term B.O.D. is then determined using an acclimated seed if such a seed is developable.

The acclimated seed was developed in a continuously aerated sample to which both phosphorous and nitrogen were added. The pH was adjusted to neutrality and trace growth factors were added by the periodic addition of tap water. The concentration of material being studied was maintained at 50 p.p.m.

Elmore (10) also found that the B.O.D. by the 5-day dilution method was not as indicative of downstream conditions as a longer period of incubation involving reaeration of the sample. As a result the following procedure is advocated:

1. Incubation of several sealed B.O.D. bottles together with an unsealed large bottle of the sample.
2. When the D.O. in the sealed bottles approaches zero, another set of samples is made up from the unsealed bottle.
3. Reaeration of the unsealed bottle is carried out before setting up a new set of sealed bottles. The reaeration is accomplished by using a magnetic stirrer, compressed air supply, a valved siphon, and a valved vent. Reaeration did not materially affect the B.O.D. reaction and a coefficient of variation of about 3 per cent could be expected.

A committee report by Stafford *et al.* (42) tabulates the 5-day B.O.D. of 154 textile chemicals and dyes. Of these 64 were determined and 90 compiled from the literature. The committee recommends that before a chemical is substituted, even though its 5-day B.O.D. is lower, both its toxicity and delayed oxygen demand be investigated.

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Chemical Oxygen Demand

Forsblad (11) in the determination of the organic compounds in lake water used a continuous evaporation in vacuo, carried out first with H_3PO_4 in order to remove chlorides and carbonates. The organic residue was then oxidized at 160° C. with a mixture of KIO_3, CrO_3, P_2O_5, concentrated H_2SO_4 and H_3PO_4. The CO_2 produced was absorbed in 0.025 M $Ba(OH)_2$ in vacuo. The amount of organic material present in the original sample was determined by titration, using both thymol-

phthalein and bromophenol blue as indicators. An accuracy of ± 1 per cent is claimed for samples containing 2 mg. of organic compounds.

Pickhardt *et al.* (36) determined the organic carbon in water solution by a so-called "simple and rapid" wet-dry combustion method. Provisions were made for the analysis of samples containing high-boiling, steam-distillable and volatile organic compounds. Halogen interferences were removed by using a scrubber containing mossy tin and stannous chloride. Solids or liquids containing organic matter equivalent to 1 to 150 mg. of CO_2 were analyzed. It was possible to analyze a 100-ml. sample, containing as little as 0.5 mg. of carbon, with a precision within 1 per cent.

When the acid permanganate method has been used for the determination of oxygen consumed in the presence of chlorides, high results have often been encountered. This was thought to be due to the partial oxidation of the chloride present. Roberts (39) proposed the possibility that these high values are due to the reaction of chlorine with some of the organic compounds present. In the presence of urea and approximately 1,500 p.p.m. of Cl^-, appreciable errors were encountered. In solutions containing less than this amount of chloride the errors were not serious. By substituting H_3PO_4 for H_2SO_4, the errors became negligible.

Dissolved Oxygen

The use of the rotating platinum electrode for the determination of dissolved oxygen has been studied by various investigators. Lynn and Okun (29), studying the continuous measurement of D.O. in sewage-sludge mixtures, found two interfering factors: (a) the electrolyte concentration (1.1 per cent Na Cl) may interfere with biological activity and (b) the filming of the electrode reduces its sensitivity. Ingols (18), using protective coatings to prevent filming, was unsuccessful in preventing interfering films. Armstrong *et al.* (1) also applied the rotating platinum electrode in D.O. determinations in oil field brines. After investigating the instruments described in the literature, the authors designed a more simple, sensitive and accurate apparatus, to study the effects of temperature, oxygen concentration and electrode design. The operation and calibration are discussed in the original paper.

Wheatland and Smith (46) checked a gasometric method against the Winkler procedure in the determination of D.O. both in distilled and saline waters. In the gasometric method, the sample was introduced into an evacuated apparatus and the liberated gases were then pumped under vacuum into a constant volume analyzing unit. The CO_2 was absorbed in 40 per cent KOH and the O_2 in an alkaline solution of sodium hydrosulfite containing Na-anthraquinonesulfonate as a catalyst. Both the regular Winkler and the azide modification were used as checks. The Winkler and the proposed gasometric method agreed within the limits of experimental error.

The D.O. determinations in the presence of sulfite waste liquor have posed a problem for the sanitary chemist. Rennerfelt (38) approached this problem by using a double sample. One sample was treated by the regular Winkler procedure while the other sample was simply made alkaline. The two samples were then acidified after the same time interval. To the sample which had been made alkaline an accurate amount of 0.01N I_2 solution was added. Both were titrated with standard $Na_2S_2O_3$ and the I_2 consumption of the second sample was used to correct the low D.O. value obtained in the first sample.

Buchoff *et al.* (4) used a reduced indigo carmine reagent for the determination of low concentrations of dissolved oxygen (0 to 50 p.p.b.) where concentration of 0 to 25 p.p.b. could

be determined visually with an average deviation of 2 p.p.b. The recommended procedure is claimed to be free from air entrapment and does not use a reagent blank or complicated sampling procedures. Its advantages lie in the simplicity and stability of the reagent and the speed with which the analysis can be carried out. Babkin (2) also used reduced indigo carmine in D.O. determinations. The leuco base was prepared by the reduction of indigo carmine with Zn-amalgam. The method was not affected by nitrites, nitrates, sulfates, chlorides, phenol, iron, zinc, ammonia and low concentrations of sulfite (< 0.3 to 0.4 p.p.m.), provided the time interval before comparing with standards does not exceed 1 hr. The effect of copper ions can be eliminated if the indigo carmine reagent contains 1 g. of Seignette salt per 100 ml. of solution.

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Organic Compounds

The determination of phenolic compounds in surface waters and industrial wastes has been the subject of numerous investigations. Eliasak (9) made an intensive study of the various methods for the determination of phenolic compounds, including colorimetric, iodometric and bromometric methods. Included in this paper is a bibliography of 156 references. Wehle (45) proposed a method for the determination of o-cresol in which this compound was oxidized to a chloroquinone. The ether extract of the latter compound developed a red color on the addition of phloroglucinol, other phenolic compounds apparently do not interfere. Pearson (35) studied the separation of phenols by chromatographic methods. He found that a mixture of phenols could be separated into groups and analyzed by ultraviolet spectroscopy.

Owens (33), in the determination of formaldehyde in sewage and river water, was able to increase the sensitivity of the method previously proposed by Schryver. By extraction of the color formed with n-butanol, interference from turbidity, iron and organic matter was eliminated. The extracted color followed Beers Law and formaldehyde was determined in concentrations of 0.1 to 0.7 mg. per liter.

The determination of anionic detergents in river water and sewage by the methylene blue method has been subjected to many modifications. Longwell and Maniece (27) in attempting to eliminate some of the interfering factors, extracted the detergent-methylene blue complex with chloroform in an alkaline solution. The combined chloroform extracts are then washed with an acid methylene blue solution and spectrophotometric readings made at 650 mu. Sodium dioctylsulfosuccinate was used in the preparation of a standard curve. This compound was suggested as a standard since it is readily available in a reagent grade and the solution is quite stable.

Tye *et al.* (43) determined benzo (α) pyrene using a series of purification steps which included vacuum distillation, sulfonation and a special two-section chromatographic column with alumina as the adsorbent and a mix-

ture of benzene and isooctane as the solvent. The fraction enriched in benzo (α) pyrene was then split into two portions. One portion was then iodized using alumina as a catalyst and a differential spectra obtained by ultraviolet spectrophotometry on the iodized and non-iodized portions. The iodization has been shown to eliminate the majority of the interferences accompanying the benzo (α) pyrene. The difference in absorption at 380, 389, and 405 mu is used in a mathematical relation designed to indicate the benzo (α) pyrene concentration.

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Nitrogen Compounds

In the determination of Kjeldahl nitrogen Louw (28) used Se, Cu and HgO as catalysts and nicotinamide as a reference sample. The digestion was carried out by using 10 g. of K_2SO_4, 1.5 g. of the catalyst and 15 ml. of concentrated H_2SO_4. With HgO as a catalyst digestion was completed after 25 min. with Cu it required 105 min., and with Se digestion was incomplete after 120 min. Reproducible results could be obtained with HgO.

Mullin and Riley (32) determined nitrate nitrogen in water by reducing it with hydrazine using Cu as a catalyst. The reduction was carried out at pH 9.6 (buffered with sodium phenate) and required about 24 hr. The method will detect about 0.3 μg. of NO_3–N per liter with a standard deviation of about 2 per cent in the range 20 to 60 μg. of NO_3–N per liter. Nitrites must be absent or corrected for NH_3 salts. Urea and amino acids do not interfere. It is recommended that if the determination cannot be carried out immediately, a filtered sample should be sterilized with 2 p.p.m. of $HgCl_2$. Hamm and Withrow (16) used a new polarographic wave in the determination of nitrate in the presence of a Cr (III)-glycine complex. The method was applicable in the concentration range of 1.0×10^{-5} to 2.5×10^{-3} mole per liter of NO_3 with as good or better precision than the older polarographic method. The effects of pH, gelatin and interfering ions were studied. The NO_2 ion gives a similar wave.

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Cyanogen Compounds

The presence of cyanide in waste waters in concentration harmful to stream life and its analytical determination in such waters is a matter of prime importance. Baker *et al.* (3) modified the Aldridge procedure in order to eliminate the effects of sulfide without their prior removal. The $S^=$ was oxidized to $SO_4^=$ at the same time forming CNBr. The method is claimed to be sensitive to less than 0.5 γ of CN^- in the presence of 2,500 γ of $S^=$ and accurate to 5 per cent at a concentration of 10 γ of cyanide. Jorgensen (19) increased the sensitivity of the Epstein procedure 5 to 6 times by a new preparation of the reagent. The bis (1-phenyl-3-methyl-5-pyrazolone) was prepared by refluxing one mole of ethylacetoacetate with three moles of phenylhydrazine for approximately 30 min. The mixed monobispyrazolone reagent was stored dry instead of as a pyridine solution. With this modified procedure 0.1 γ of CN^- can be determined with a standard deviation of ± 3 per cent.

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Phosphorus Compounds

Permanent color standards for the determination of phosphate in the range 10 to 100 p.p.b. by the molybdenum blue method were prepared by Parry and McClelland (34), using mixtures of 4.88 g. of $CuSO_4$ and 0.92 mg. of bromophenol blue in 10 ml. of a NaAc-HAc buffer solution (pH 4.53). Levine *et al.* (26) established the range of conditions under which phosphorus could be determined in the presence of up to 10 p.p.m. of the oxides of arsenic, silica and germanium by the molybdenum blue method. The $PO_4^=$ was concentrated by coprecipitation with $Al(OH)_3$. Quinlan and Debra (37) used the molybdovanadate method in the determination of phosphorous in the range of 3 to 20 p.p.m. (P_2O_5). The optimum concentration of acid, vanadium (V) and molybdenum (VI) were determined by factorial experiments and found to be 0.4 mole in acid, 0.02 to 0.06 mole in molybdenum and 1 to 4 moles in vanadium (V).

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Sulfur Compounds

Fritz and Yamamura (13) determined low concentrations of sulfate by titrating with 0.005 mole barium perchlorate in the presence of Thorin [2-(2-hydroxy-3, 6-disulfo-1-naphthylazo) benzenearsonic acid)] in an 80 per cent alcohol solution in the pH range 2.5 to 4.0. The method was more versatile and accurate if the cations were removed before titration by means of an ion exchange column. Phosphate interfered with the method but could be removed by precipitation with $MgCO_3$. The method was applied to the determination of sulfates in raw water, treated water and boiler water. Concentrations of $SO_4^=$ as low as 10 p.p.m. could be determined within ± 1.0 p.p.m. With higher $SO_4^=$ concentrations, the error is about 1 per cent. Sulfates in concentrations of 0 to 400 p.p.m. were determined colorimetrically by Lambert *et al.* (24) using an insoluble thorium borate-amaranth dye reagent. The $SO_4^=$ ion releases dye in direct proportion to its concentration. The amount of dye released was measured photometrically at 521 mμ. Interference due to F^-, $PO_4^=$, and HCO_3^-

was removed by use of added lanthanum ion and a weak cation exchange resin. The results obtained by this method were in good agreement with the gravimetric procedure.

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Halogen Compounds

With the increase in fluoridation of potable water supplies, an increased demand for more accurate fluoride determination methods has resulted. Frazier (12) studied the use of portable field kits (using permanent standards) for this determination and the limitations and precautions necessary in their use. The presence of polyphosphates and aluminates in the sample interfered, requiring use of a distillation procedure. However, permanent standards are considered satisfactory and correct results can be obtained to within 0.1 p.p.m. Kramer (22) discussed different color intensities resulting from the use of different batch samples of alizarin and stated that a check is necessary each time a different Zr-alizarin reagent is made. Lamar and Drake (23) discussed the determination of fluoride by means of the Zr-alizarin method. An accuracy of 0.1 p.p.m. could be obtained if readings are made after a 7-hr. contact time. A 1-hr. period can be used if precise reaction times and temperatures are maintained. Interferences due to Al^{+++}, $PO_4^{=}$ and free chlorine are especially critical. Correction for phosphate is particularly hard to make and if more than 0.2 mg. is present in the aliquot taken, then the distillation step is necessary. Interference from common ions such as Ca (200 p.p.m.), Mg (200 p.p.m.), Na (1,000 p.p.m.), K (200 p.p.m.), and NO_3 (300 p.p.m.) were not serious. Hexavalent chromium (0.05 to 0.06 mg.) and Fe (2.5 mg.) in the aliquot interfere with the method. Krahulec (21) proposed a new method for the determination of fluoride for which a sensitivity of 0.01 p.p.m. is claimed. This method is based on the decolorization of a Zr-pyrocatecholsulfonphthalein (pyrocatechol violet) reagent by the fluoride ion. The color change is measured at 525 mμ. It was found that the color reactions with the Ti (IV) and Th (IV) complexes were not suitable. Schall and Williamson (40)(41) studied the determination of fluoride as well as an automatic distillation apparatus. The determination was made by measuring the bleaching action of fluoride on the complex formed between titanium and ascorbic acid in a solution buffered at pH 4.0 to 4.5. The intensity of the color is dependent on the concentration of both titanium and ascorbic acid, the absorbance being measured at 360 mμ. The method will detect approximately 1 p.p.m. of fluoride. Apparatus was described (41), in which the temperature was automatically controlled ($\pm$ 1.0° C.) by regulating the addition of water. The rate of distillation was about 200 ml. per hour. The apparatus consisted of a modified Claisen distilling flask, mercury thermoregulator, solenoid valve and a relay.

Lambert and Yasuda (25) determined the chloride ion colorimetrically in the concentration range of 0 to 180 p.p.m., using a granular silver iodate column in which the chloride ion was exchanged for the iodate ion. The eluted iodate ion was then reacted with cadmium iodide-linear starch reagent and the absorbance of the blue color formed at 615 mμ was measured. None of the ions in concentrations commonly present in natural waters

caused interference. In the turbidimetric determination of chloride in the range of 0.01 to 3.0 p.p.m., Kitano and Tsubata (20) were able to stabilize the colloidal AgCl by the addition of a lead salt. The reagent used contained 0.001 mole of $AgNO_3$ per liter and 0.02 mole of $Pb(NO_3)_2$ per liter. After addition of this reagent to the sample, the mixture was placed in the dark for 20 min. The resultant turbidity was then compared with a standard series in Nessler tubes.

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Metallic Ions

The role that metallic ions play in sewage and water treatment processes and the biological balance in streams has received increasing attention in recent years. This is not only true for the more common metallic ions but also for the rare earth elements as well. In the flame photometric determination of strontium in sea water, Chow and Thompson (6) showed that Ca^{++} ions alone displayed band-width interference. Chloride, $SO_4^{=}$ and Mg^{++} ions showed negative interference when "internal standards" were used. Sea water samples gave a strontium-chlorinity ratio of $0.0048 \pm .002$ where strontium is expressed as milligram atoms. Hoste and Gillis (17) determined selenium in trace quantities by use of diaminobenzidine, and found that the reaction was very sensitive, the molecular extinction coefficient being as high as 10,200. It is also specific since the common ions which are likely to occur, cause no interference.

One of the difficulties often encountered in the determination of trace amounts of metallic ions is the possibility of adsorption on the glassware used. This was demonstrated by Gubin *et al.* (15) in which three cooperating laboratories analyzed 10 water samples containing 0 to 50 γ of Cu per liter. The results obtained showed too much variance, so a second analysis was made using new Jena glass flasks. The results obtained with this set of samples showed fewer discrepancies, and it was found that the wide variance in the first set was due to variable adsorption on the glass. As a result, a special flask was used. The color was developed with diethyldithiocarbamate and extracted with chloroform.

Urone (44) studied the stability and sensitivity of S-dipbenylsemicarbazide reagent for the determination of chromium using a variety of solvents. Nonaqueous ethyl acetate and acetone solutions of this compound were stable for months. All solvents tending to be basic or containing traces of water were not satisfactory. When methyl ethyl ketone or methyl cellosolve were used, the reagent was stable for one to two weeks.

Dippel and Bricker (8) determined manganese by means of the flame photometer with the intensity of the Mn line at 403.3 mμ. Inhibition or enhancement of this line by other ions present was corrected for by using "in-

ternal standards." Background radiation in the vicinity of the 403.3 line can be detected from the emission intensity at 400 and 406 mμ respectively and the proper correction applied without affecting the "internal standard" procedure.

Chow and Thompson (5) investigated the determination of calcium in sea water. Chloride, Mg^{++}, K^{+}, and $SO_4^{=}$ ions showed negative interference while Na^{+} showed positive interference. By use of the "internal standards" technique interferences were minimized. A calcium-chlorinity ratio of 0.546 ± 0.002 (expressed as milligram-atoms of Ca) was found for waters in the Gulf of Alaska. This agrees with previously reported results.

Menis and Rains (30) found that palladium formed a yellow complex with furildioxime in an HCl solution. This complex could be extracted with $CHCl_3$, and its absorbance measured at 380 mμ. In the aqueous phase, the complex was stable for only 20 min., while in the $CHCl_3$ extract, it was stable for about 24 hr. Gold and platinum did not interfere, while cyanide prevented the formation of the Pd complex. The method is sensitive to 0.1 p.p.m. of Pd.

Dean and Lady (7) found that by extracting iron with acetylacetone (which also serves as a chelating agent) and aspirating the extract directly into the flame photometer, the intensity of the Fe line at 372 mμ was increased six-fold. There was no interference when the method was applied to Al, Cu, and Ni-base alloy or to limestone. Replicate samples showed a standard deviation of 3 per cent.

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Miscellaneous Papers

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SEWAGE

Physical and Chemical Methods

Ingersoll, McKee and Brooks (43) reviewed the fundamental concepts of sedimentation in rectangular settling tanks, with particular reference to the effects of shape, inlet and outlet arrangements and baffling on the efficiency of removal. The theories of Hazen, Camp *et al.*, indicating that sedimentation efficiency is a function of surface area and that settling tanks should be long, narrow and relatively shallow, are reiterated and supported. A new method of comparing the performance of existing tanks, which takes into account the distribution of sizes of the suspended matter, is proposed. Experimental results with wax spheres and silica verify that the removal is independent of the depth. However, bottom scour may be an important factor in shallow basins in which the forward velocity is greater than 9 to 15 times the settling velocity of the smallest particles for which complete removal is desired. To minimize the effects of inlet turbulence, the length to width ratio should be no less than 10. Large bottom area should be provided for sludge thickening, since a given volume of sludge will thicken more rapidly during early stages of compaction in a thin blanket than in a deep one. The authors suggest that settling tanks for water or sewage works can be made relatively shallow provided that multiple inclined baffles are provided to prevent the resuspension of the bottom sludge.

In discussing the paper of Ingersoll *et al.*, Camp (19) discusses the theoretical aspects of bottom scour and suggests that the average tank velocity can be considerably greater than proposed. Thockwell (89) describes a system of baffling in a rectangular settling tank of low length to width ratio which resulted in efficient removal of alum floc.

Fischerstrom (30) discusses the design of rectangular settling tanks, with particular emphasis on the design criteria which are necessary to insure stable flow patterns. In order to minimize the retardation of settling by turbulence, the Reynolds Number, VR/v, should be kept as low as possible. On the other hand, to promote flow stability the Froude Number, V^2/R_g, should be as high as possible. Increasing the wetted perimeter serves to both decrease the Reynolds Number and increase the Froude Number. This suggests the use of longitudinal baffles. If the baffles are arranged as horizontal trays, so as to provide for multiple story basins, the settling efficiency will also be increased by virtue of the greater overflow rate. Presented are comparative performance data on full scale settling tanks which were improved by the insertion of longtudinal baffles. A unique multiple story tank that has been designed for use as a secondary settling tank for activated sludge is described.

Kohlschutter (50) discusses the design of mixing basins to provide homogeneous mixing of liquid wastes which may vary in composition from time to time. This is accomplished hydraulically, without paddles, by distributing the inflow to a tank of such shape that different portions of the waste spend varying amounts of time in the tanks. The mathematical theories for tanks of various shapes are developed.

Stone (87) discusses the treatment of domestic and industrial sewages by precipitation with aluminum sulfate with and without the aid of lime and sulfuric acid. The criterion of purification was the 4-hr. oxygen absorption from N/80 permanganate. At least 150 p.p.m. of aluminum sulfate

were needed for domestic sewage, and up to 250 p.p.m. for industrial sewage. The effect of pH on the results obtained with several dosage rates of aluminum sulfate is discussed.

Biological Filtration

The biological filtration experiments conducted at Reading, England between 1949 and 1954 were summarized by Barraclough (7) and can be divided into studies of alternating double filtration, recirculating filtration and first-stage high-rate filtration. Media in the 9 filters used ranged from 1¼ to 4 in. in size. With the exception of the filter containing the 4-in. medium, surface ponding developed rapidly under high-rate filtration and that phase of the investigation was abandoned. Alternating double filtration and recirculation studies revealed that better effluents were obtained with the smaller media. Good results, however, were dependent on the absence of ponding which least affected the alternating double filtration process. A loading of 50 gal. per cubic yard per day was suggested as the basis of design for straight filtration with 100 gal. per cubic yard per day for alternating double filtration or recirculating filters.

The efficiency of a trickling filter is appreciably affected by the rotational speed of the distributor arm. A study by Tomlinson and Hall (92) revealed that the optimum rotational speed of a four-arm distributor studied at Minworth, Eng., was in the range of one revolution in 15 to 30 min. Optimum periods of dosing will vary within certain limits, depending on the filter, the rate of treatment and method of operation. The speed of the rotating distributors of two large experimental filters was mechanically controlled so that one revolution could be made in 8, 15, 20, 42, and 55 min. Two other filters, using the jet action of the discharging sewage for propulsion, were used as checks. The average speed of the jet driven distributor varied from 1 to 5 min. per revolution. Settled sewage having an average B.O.D. value of 227 p.p.m. was applied at an average rate of 150 gal. per cubic yard per day. The most noticeable effect due to the variation of distributor speed was the elimination of surface growth of fungus during January to March on the slower driven filters, and the substitution of a thin algal film similar to that which occurs on all the filters during the summer. It was also observed that the surface film on the filters with the faster moving distributor was two to three times as much as on the filters with the slower operating distributor. Surface ponding, which occurred regularly with the jet driven distributor, did not occur when the rotational speed was reduced. The efficiency of the filters with the slower driven distributor was more constant and was at a higher level than with the jet driven distributor.

Hawkes (39), discussing the effect of the slower distributor rotating speeds on the bacterial population, states that the period of dosing has a marked effect on the accumulation of film and on the grazing fauna. He attributes the small amounts of slime to starvation of the organism and to the scouring action of the sewage due to the high velocity of application. A reduction of filter flies when the speed of rotation is decreased is attributed to the reduction of slimes which protect and feed the fly larva.

Feldman (28) isolated and identified six species of molds found in three trickling filters receiving a dilute chemical waste of high organic content. The molds were *Fusarium solani, Fusarium roseum, Fusarium moniliforme, Geotrichum candidum, Geotrichum* sp. and *Alternaria tenuis.*

Becker and Shaw (10) studied the fungi present in different units of two municipal sewage treatment plants which use two-stage trickling filters. Direct microscopic examination of various effluents did not reveal true fungus mycilium except when the filter had an abundant growth of fungi.

Slimes from the primary filter did not reveal the presence of fungi. Cultural methods used indicated that liquid samples from the later stages of treatment had lower fungal population than in the earlier stages. The primary filter in one of the treatment plants developed an orange color due to the presence of *Fusarium aquaeductuum*, although the effluent from the filter did not show an increase in the fragments. Yeasts are eliminated from raw sewage as it passes through the treatment plant.

Various aspects of the nutrition of four fungi which commonly inhabit trickling filters were studied by Painter (67). *Sepedonium* sp. required organic sources of nitrogen while *Fusarium aquaeductuum, Geotrichum* sp., and *Trichosporon cutaneum* were able to utilize ammonium salts; *F. aquaeductuum* was also able to utilize nitrate. *Geotrichum* sp. and *F. aquaeductuum* needed no external supply of vitamins. *T. cutaneum* required thiomine and *Sepedonium* sp. required thiomine and biotin for optimum growth. The pH range for optimum growth was narrow (pH 7 to 8.5) for *Sepedonium* sp., while the ranges for the other fungi were much wider (pH 3 to 9). Zinc, Ca, Mn and probably Fe and Cu were required by *Sepedonium* sp. which was the only one of the four fungi inhibited by concentrations of Zn above the optimum in media partially deficient in other elements. When Mn, Fe or Cu was added with Zn the inhibitory action was counteracted while the addition of Ca with Zn increased it.

Gaillard (34) studied the effect of treating domestic sewage containing gas liquor on experimental trickling filters. The addition of spent liquor to sewage did not cause any greater deterioration in the quality of the effluent with increased loadings. With crude liquor additions, the effluent B.O.D. for a given filter loading was increased by about 50 per cent. The quantity of crude liquor that could be tolerated without affecting the quality of the effluent was one-half the quantity of spent liquor. Also mentioned were the relative effects of spent and crude liquors on nitrification.

Trickling filter performance, as affected by B.O.D., suspended solids and hydraulic loading rate, was reported by Sorrels and Zeller (84). With a recirculation ratio of 1:1 hydraulic loading rates were varied from 3.5 to 11.5 m.g.a.d. When the recirculation was increased to 1:2 the hydraulic loading rate varied from 5.0 to 16.6 m.g.a.d. The organic loading rates were approximately 500, 800, 1,200, and 1,750 lb. of 5-day B.O.D. per acre-foot per day. Although the amount of B.O.D. removed by the filter, either with or without recirculation, increased as the organic load is increased, the rate of removal decreased so that an effluent of poorer quality resulted from the heavier loaded filter. It was also observed that the hydraulic loading rate has a significant effect on filter performance. While maintaining the same B.O.D. loading and increasing the hydraulic loading rate, there was a decrease in the percentage of B.O.D. removed and an increase in the amount discharged in the effluent.

Furman, Calaway and Grantham (33) investigated the effects of multiple loadings on the efficiency of intermittent sand filters. While greater removal of 5-day B.O.D. was achieved by loading filters containing 0.25 mm. and 0.31 mm. sands twice each day rather than once, there was little improvement when the sewage was applied 4 or 24 times each day. Increasing the number of loadings beyond twice per day, however, appreciably increased the efficiency of filters containing 0.45 mm. and 1.04 mm. sands.

Thompson, Lagnese and Hanson (91), in discussing waste disposal at Air Force installations, reveal that standard-rate trickling filters are generally recommended for secondary treatment and are designed for an organic loading of 600 lb. of B.O.D. per

acre-foot per day for an 80 per cent B.O.D. removal. Where high-rate trickling filters are used they are designed for an average organic loading of 3,000 lb. of B.O.D. per acre-foot per day, and a recirculation ratio of 1.5:1 for a B.O.D. reduction of 75 per cent.

The trickling filters at Dallas (Texas), although loaded up to and in excess of 1,000 lb. of B.O.D. per acre-foot per day, produced an effluent with an average B.O.D. of 27 p.p.m. and an over-all reduction of 91.5 per cent. Williams and Graeser (100), in reporting this study, state the operation was primarily a single-stage treatment with recirculation practiced only during periods of low flows. When completion of the additions to the Dallas plant permitted second-stage treatment, the over-all B.O.D. removal was increased to 94.8 per cent with an effluent containing 20 p.p.m. B.O.D.

The use of a molded polystyrene plastic as trickling filter media was investigated by Bryan (16). This material is manufactured as a modified berl saddle or a corrugated sheet. The corrugated sheet, which provides equal surface area per unit of occupied volume with about one-half the weight of the modified berl saddle, was employed as a trickling filter medium. Using a synthetic phenol waste it was demonstrated that the medium is suitable for the attachment of active biological slimes and produces a better effluent than conventional media. The chief advantages of the plastic media over the more common types are said to be low unit weight, high ratio of void space to total volume occupied, high surface-area-to-volume ratio, excellent free vent characteristics, non-clogging tendency, flexibility of design and ease of assembly and packing. It is expected that when increase performance factors are incorporated into the design, the cost of the plastic media will compare favorably with that of conventional types.

Reid (77) points out that while considerable progress has been made in the technology of waste disposal by biological methods little has been done toward finding ways to utilize the valuable materials produced. An average of 8,300 lb. of nitrogen and 2,500 lb. of phosphorus are discharged each day in the sewage effluent from the Southside sewage treatment plant, Oklahoma City, Okla. This represents as much phosphate as is contained in approximately 60,000 lb. of commercial fertilizer. The use of algae to harvest these elements is recommended.

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Activated Sludge

Several articles were published during 1955 on the rate of oxygen transfer and the respiration of microorganisms. King (46)(47)(48) developed formulas for computing the rate of oxygen

absorption in spiral flow aeration tanks with porous plate diffusers and checked them on large aeration tanks. He determined the effects of such factors as the air application rate, air bubble diameter, oxygen deficiency, water temperature and pollution and gave examples to show the application of the formulas to design and research. Pasveer (68) found that the rate of purification is not controlled by the temperature but by the oxygen supply, the latter is always the most important factor. The rate of biochemical oxidation can be increased at least 50 times the usual rate by increasing the oxygenation capacity. Pasveer (69) has derived equations for computing the amount of oxygen which goes into solution from an air bubble. Weston and Eckenfelder (99) have developed a theory to explain the kinetics and equilibria of biological oxidation systems, based on a three-phase process consisting of: (a) an initial high-rate removal of B.O.D. obtained when sludge and sewage are mixed; (b) a slower removal of B.O.D. which is directly proportional to biological cell growth; and (c) oxidation of biological cell material with a concurrent low-rate of B.O.D. removal. Equations have been developed to express the relationships between the various factors involved.

Kraus (51) reports that turbulence is a more important factor in aeration than bubble size, depth of submergence or contact time. A dual aeration system has been developed where part of the air is admitted through diffusers at the bottom and part is distributed at shallow submergence to create maximum turbulence. Lower power costs and better oxygen absorption efficiency result. The dual aeration system and a modification of the activated sludge process, which includes reaeration of a mixture of return sludge and digested sludge, resulted in an increase in aeration tank loading (B.O.D. per 1,000 cu. ft. per day) of at least two to three times greater than the normal design value. There was not an appreciable reduction in degree of purification.

Oxygen utilization rate of *Z. ramigera* in substrates containing various types of organic nitrogenous material was determined by Rich (78) by measuring the D.O. change polarographically (dropping mercury electrode). The vessels in which D.O. was determined were open to the atmosphere and not agitated. The diffusion of oxygen from the atmosphere was assumed to be negligible. Preliminary studies indicated that the mercury had no effect on the respiration of the organism. The oxygen utilization rate in various substrates was highest during the first 15 min. than subsequently up to 60 min. *Zooglea ramigera* exhibited a marked preference for proteoses and peptones over purified proteins and amino acids. The latter are utilized at about the same rate. Gelatin was utilized although it cannot be liquefied by this organism. Glucose was utilized at a slow rate. Ammonium ions (25 p.p.m. or more) reduced the respiration rate of *Zooglea ramigera.*

Using Warburg apparatus, Moses and Syrett (61) studied the effect of an external substrate on endogenous respiration. Using microbial cells tagged with C^{14} and an unlabeled substrate, the CO_2 produced should be inactive if endogenous respiration were completely suppressed by the added substrate. In general, $C^{14}O_2$ production by the alga, *Chlorella vulgaris,* the fungus, *Zygorhyncus moelleri* and baker's yeast in the presence of external oxidizable substrate was either unaffected or stimulated. Sodium azide and 2:4 dinitrophenol stimulated endogenous respiration but glucose, with an inhibitor, suppressed the increased rate of $C^{14}O_2$ evolution. Longmuir (55) found that the respiration rate of bacteria is related to the oxygen concentration by the Michaelis-Menton equation. A critical review of the information on the principles and tech-

niques of oxygen transfer was presented by Finn (29).

Mechanical air dispersers have also been examined to determine characteristics under various conditions. Kalinske (45) described a mechanical disperser in which small bubbles are produced by injecting compressed air into a liquid entering the inlet of an impeller near the bottom of a circular aeration tank. Although efficiencies in the order of 30 to 40 per cent can be obtained, the high cost of power makes it uneconomical except under special circumstances. Oxygen absorption efficiencies of 10 to 12 per cent would be most economical as far as total power consumption is concerned. High oxygen absorption efficiencies would permit the use of higher concentrations of aeration solids and the treatment of stronger organic wastes. Chain *et al.* (20) investigated the relative efficiency of several aeration devices and found that, with no agitation, a sparger of porous material was twice as efficient as a ring sparger with 90 holes at air flows from 0.2 to 1 volume of air per volume of liquid per minute. Agitation considerably increased the rate of aeration. At a propeller speed of 500 r.p.m., the porous sparger was three times as efficient as the ring sparger, but at higher propeller speeds the difference became less pronounced. Aeration was most efficient when the propellers were located at one-half the liquid depth. Use of a propeller without baffles creates a vortex which interferes with mixing but the vortex can be used for efficient and economical aeration without the injection of air into the liquid.

The effect of reduced sulfur compounds was studied by Aulenbach and Heukelekian (3), who found that activated sludge can be acclimated to oxidize up to 500 mg. per liter of sulfite sulfur to sulfate in a 6-hr. aeration period. Sulfite is not toxic to activated sludge but it requires large amounts of oxygen. Sulfides reduce the activity of activated sludge but the sludge can be acclimated to purify sewage containing 25 mg. per liter, and 50 mg. per liter can be tolerated for about a week. Thiosulfate in the amount of 750 mg. per liter can be oxidized in a 6-hr. aeration period with proper acclimated sludge. Greenberg, Klein and Kaufman (35) found that phosphorus deficiencies caused poor B.O.D. removal and produced poor settling sludge with many filamentous organisms. The development of activated sludge is not possible in the complete absence of phosphorus. The phosphorus requirement in the experiments, expressed as a ratio to B.O.D. removal, was 1 to 238. In an investigation of the toxicity of metals in mixtures of sewage and activated sludge, Heukelekian and Gellman (41) found the order of decreasing toxicity was nickel, copper, zinc, cobalt and hexavalent chromium. The retarding effect on oxygen utilization occurred after prolonged periods of aeration rather than during the initial period. According to Pillai *et al.* (71), as little as 4 mg. per liter of aureomycin adversely affected the clarifying action of sludge. The bacterial content was not appreciably affected but the protozoal activity and clarification decreased in proportion to the strength of the aureomycin. Penicillin and streptomycin acted about the same as aureomycin. McKinney and Jeris (57) studied the metabolism of low molecular weight alcohols using activated sludge acclimated to simple alcohols. The normal alcohols above methanol followed the pattern of normal oxidation from alcohol to aldehyde to organic acid. The methanol acclimated sludge was able to utilize methanol and to a lesser extent formic acid but not formaldehyde. The isoalcohols followed two patterns of metabolism. Isopropanol showed a retarded pattern from the normal alcohols but isobutanol followed the normal course of oxidation.

Haseltine (38), in an excellent paper on a rational approach to design, has suggested that loading should not ex-

ceed 50 lb. of B.O.D. per 100 lb. of aeration tank solids and that moderate to large sewage treatment plants should be designed to operate at a Mohlman Index of 250. This would indicate a return sludge concentration of 4,000 mg. per liter. The air required should be based on the ratio of B.O.D. to aeration tank solids as well as on total B.O.D. input.

According to Möhle (59), the new high-rate activated sludge plant at Wuppertal-Buchenhofen (Germany) has treated an average of 9 m.g.d. with 1.75 hr. aeration. The air ratio was 0.51 cu. ft. per gal. of sewage and the B.O.D. removal in the aeration system 72 per cent. About 500 cu. ft. of air were required for each pound of B.O.D. removed. Air was added to the sewage through open pipes in a tapered pattern from the influent to the effluent end of the aeration tank. If necessary, diffuser plates or tubes can be added later. The sludge contained bacteria and flagellates but no other protozoa. Pöpel (74) stated that, in high-rate plants, best results are obtained with high concentration of solids in the aerator and short aeration periods. The concentration of activated sludge in the aerator depends on the efficiency of aeration. For relatively high solids, large bubble aeration is satisfactory.

Torpey and Chasick (95) discussed the principles involved in the modifications of the activated sludge process—step aeration, modified aeration and activated aeration, and described methods of operation for these processes.

An improved centrifuge capable of concentrating waste activated sludge from 0.8 per cent solids to 5 per cent solids at rates of 50 to 67 g.p.m. discharged an effluent containing only 250 mg. per liter suspended solids. According to Bradney and Bragstad (13), the results of these centrifuge operations, which show great improvement over those obtained with earlier models, have indicated benefits at Sioux Falls, S. D. which justify the operating cost.

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Disinfection

Considering the complexities and unknown factors in the disinfection of sewage, a relatively small amount of data was published during 1955. Grune (37) presented a comprehensive review of sewage chlorination, including a list of 31 references and tabulated data pertaining to dosage requirements, chemical and bacteriological effects, and toxicological effects of chlorine. A selected bibliography covers the period 1927 to date.

Popp (75) conducted studies on the bacteriological effect of chlorine in water. Surviving organisms were counted within 12 sec. to 60 min. after mixing the organisms (*Escherichia coli*) with chlorine. Free and combined available chlorine was also determined. Tests were made using chlorine dosages up to 0.6 p.p.m. at different pH values and initial bacterial numbers. It was found that the reduction of organisms does not follow the exponential law but occurs as an initial rapid reduction of organisms lasting 12 sec., followed by a slow reduction. The first phase is more pronounced with a high chlorine to organisms ratio and also at low pH values. Between pH 7.5 to 10, the reduction is small. The killing action of

chlorine is used up during the initial contact period and free available chlorine, determined after 30 sec. of the addition of orthotolidine, is a measure of bacterial killing power, which a 5-min. reading does not give. The first exponential step is due to the nascent HOCl molecules. Combined available chlorine formed thereafter is less active and slower.

Lethal activity of chlorine and ozone on *E. coli* was studied by Bringmann (15). Ozone in contrast with chlorine has a general oxidation of cytoplasm and does not produce selective injury to vital centers.

A formula for calculation of disinfection requirements called a "decontamination factor" was presented by Thomas (90) in a report on disinfection in military sewage treatment plants. The formula is designed for approximate calculation of appropriate degrees of disinfection in areas lacking suitable regulations.

According to Bogat *et al.* (12), chlorination of San Francisco's North Point Sewage Treatment Plant effluent with 100 lb. per million gallons for 10 months each year effectively reduces the coliform density of the previously treated sewage and markedly improved the bacterial quality of the receiving water. Nusbaum and Garver (64) report some studies on the viability of enteric organisms in sea water.

It was reported (2) that a free chlorine residual of 0.1 to 0.3 p.p.m. in the effluent of the Celoron-West Ellicot Sewage Plant maintained the M.P.N. of coliform bacteria at less than 40 per 100 ml. with only two exceptions. At Laconia, N. H., a study indicated that a minimum chlorine dosage of 14 p.p.m. and/or 1.0 p.p.m. residual produced an acceptable effluent (1).

Effective control of *Desulfovibrio*, the bacterium responsible for the production of sulfide from sulfate, by chlorination was studied by Vickers and Williams (96). They reported that the organisms were inhibited by a chlorine dosage that was less than the amount required to satisfy the demand of the water and leave a residual after a 5-min. contact time. The organisms suspended in distilled water were inhibited with 0.07 p.p.m. of combined available chlorine after 5 or 10 min. of contact time.

Studies continue on the use of ultraviolet light as a means of disinfection of water and sewage. Hoather (42) studied the effects when using a maximum sample depth of 1 in. Cost of this method exceeds that for chlorination. Another product in the disinfection field, hexachlorocyclopentadiene, was compared with chlorine by Cole (23). A tabulation of comparative kills of organisms by this compound and chlorine indicates that in the conditions of the experiment this compound seemed to be somewhat more effective than chlorine. Cost comparisons were not given.

Problems of sewage disposal in Arctic areas led Chang *et al.* (21) to study the effect of subfreezing temperatures on cysts of *E. histolytica*. Dehydration through crystallization of water in the cysts killed them in a few hours at $-11°$ C.

Sludge Digestion

Theory and Mechanism

Relatively little new information on the theory of sludge digestion was reported in 1955. Grune and Sload (36) investigated the possible effect of widespread fluoridation of water supplies. Assuming that one-half of the normal 1 p.p.m. of fluoride involved might appear in sewage sludge, these investigators applied a factor of ten in their experiments. In a batch digester 5 p.p.m. of NaF did not affect gas production nor produce other deleterious effects. It was concluded that the normal fluoride content of sewage will not be detrimental to the digestion of sewage solids.

A study of the effects of several sulfur compounds was made by Aulenbach and Heukelekian (4). The com-

pounds used and their amounts in terms of sulfur were: sulfite, up to 250 p.p.m.; neutral soluble sulfide, up to 250 p.p.m.; sulfides of various solubilities and reaction; and organic sulfur in the form of cystine and methionine, up to 1,000 p.p.m. It was found that 50 p.p.m. of sulfite (as sulfur) retarded digestion, while 100 p.p.m. inhibited digestion completely. The action seems to be one of retardation of gasification, resulting in accumulation of digestion-retarding volatile acids. In the digester, the sulfite was reduced to thiosulfate and then to sulfide which further retarded digestion. Factors such as solubility, acidity and concentration of sulfide were found to govern the degree of interference. Neutral soluble sulfides interfered with gasification in the 100 p.p.m. range by inhibiting organisms and thus increasing the volatile acids. At 150 p.p.m. a tendency to reduce liquefaction also was apparent. The organic sulfur compounds were not in themselves inhibiting. Cystine broke down to sulfide and at 100 p.p.m. (as sulfur) digestion was retarded while at 500 p.p.m. gasification stopped. Methionine showed little breakdown and had no important effect in concentrations up to 1,000 p.p.m.

Pine and Barker (72) studied the ability of methane producing bacteria to fix nitrogen as do several other anaerobic bacteria which possess hydrogenase. *Methanobacterium omelanskii* was used in experiments in which *Chlorobium thiosulfatophilum* and *E. coli* served as positive and negative controls. N^{15-} labeled N_2 was found to be fixed to some degree when NH_3 was present in an amount barely sufficient to initiate growth. Higher amounts of NH_3 stimulated growth but abolished fixation. It was concluded that the test organism is inefficient as a nitrogen fixer, but under better test conditions the extent of fixation might be increased. A method for determining the number of methanogenic bacteria in sludge was developed by Mylorie and Hungate (63). A substrate of hydrogen and CO_2, with palladium as a reduction catalyst, was used. Fifteen strains of methane producers, classified as *Methanobacterium formicicum* were pure cultured and their efficiency and rate of fermentation studied. The culture count ranged between 10^5 and 10^8 per milliliter.

Evreinova *et al.* (27) found active amyolytic enzymes adsorbed on the sludge in methane-generating septic tanks. The amyolytic activity declines with time in the digester. An increase in starch content leads to a similar increase in time required for cleavage of starch by the amylases in the tank. Proteases were found both in the sludge and in the clear supernatant. Experiments with a Swiss enzyme preparation were reported by Vrijburg (97). Microscopic examination showed the inoculum to be a mixture of various microorganisms. In the digester it did not increase gas production in 20 days, but after 5 days at 20° C. it increased slightly the $KMnO_4$ number and the sludge B.O.D. Lesslie (54) concluded from an experiment in starting two digesters in the absence of available seed sludge that a commercial inoculum reduced materially the time required for full gas production but that it compared unfavorably with seed sludge from an active digester. Wells and McKinney (98) used the same biocatalyst in a 28-week study of two plant-scale open digesters. Their findings supported the 1954 conclusions of Heukelekian and Berger that the addition of bacterial cultures and enzymes to sewage solids cannot result in material improvement in digestion.

New Developments

The development of high-rate sludge digestion through process modifications continued to hold the interest of engineers in 1955. Lee (53) noted that New York City, N. Y. was designing a full-scale digester for 0.5 cu. ft. per capita, on the basis of a pilot test which indicated that by mixing, con-

trol of temperature, etc. sludge storage can be reduced to 0.2 cu. ft. per capita. Torpey (94) loaded a pilot-scale digester to failure to explore the limits of digester loading after the digesters at the Bowery plant had been observed to operate satisfactorily at design loadings of 0.5 cu. ft. per capita. A thickened primary and activated sludge mixture was added at 2-hr. intervals without interruption for 7 months, at periodically increased rates until failure occurred. The results show that a 5-day detention period, equivalent to a loading of 0.2 cu. ft. per capita is desirable. If, however, it is desired to obtain practically all of the available gas, 0.4 cu. ft. per capita is required.

In discussing these results, Schlenz (94)(81) pointed out that loading values such as 0.2 or 0.4 cu. ft. per capita as a basis for design could not be supported by the data presented. He noted a recent tendency to reverse the 1928–1936 trend toward increased loadings and to go to 5 to 6 cu. ft. per capita for activated sludge. He cautioned against extrapolating from small laboratory experiments to plant-scale operation, as well as the uncritical acceptance of plant studies in which only the use of other digesters in various manners made possible the high-rate operation of one. Optimism based on recent experiments ignores the fact that a high percentage of gas in a short period is not an indication of high-rate digestion; that the degree of digestion necessary for sludge drying, the need for sludge ripening and thickening, and provision for grit all require storage capacity; that allowances must be made for non-uniformity of sludge volume and quality; and that compensation must be made for careless operation and lack of trained technical personnel in a plant. Heukelekian (94) agreed in his discussion of Torpey's paper that a combination of sludge thickening, effective use of tank volume and uniform feeding of sludge makes high-rate digestion possible. He posed questions concerning the practical problems of constant feeding rates and the means of mixing on a plant-scale basis. King (94) doubted that the full capacity of a tank can be utilized in a plant-scale unit. There was general agreement that the degree of operation required in high-rate sludge digestion is not likely to be attained in most treatment plants. Lee (53) also doubted that extreme tank loadings would be suitable for small communities.

Sawyer and Schmidt (79) conducted laboratory studies to evaluate the concept that continuous mixing and agitation of the entire digester content, as well as the recirculation of gas and the pre-thickening of sludge, are important to high-rate digestion. They concluded that loadings are a function of solids concentration, with 4 per cent solids giving best results; that thickening is required to reduce the detention period to 15 days, but with thickening the period may be as short as 11 days; and that several practical considerations are involved. Copeland (24) added to the general list of requirements for high-rate digestion the considerations that scum must be reduced to less than 2 ft. in thickness and the tank kept free of accumulations of grit or of cold dense layers of undigested matter.

Pöpel (73) described investigations to determine the applicability of mathematical expressions of the rate of development of bacterial populations to the design of sewage digestion tanks. A study of existing large treatment plants showed good agreement between calculated and observed values.

Means of obtaining good circulation of tank contents necessary to high-rate digestion were indicated by several authors. Crist (25) noted that fixed cover digesters are better suited to continuous mixing than are those equipped with movable covers. For the Bowery Bay (N. Y.) plant O'Leary (65) reported that fixed steel covers equipped with three down-draft tube mixers capable of turning over the tank contents

in 1 hr. showed such possibilities that one-half of the 8 proposed digesters were eliminated in the final plant design. For reasons of economy and efficiency, Braine (14) suggested a covered primary digester with open wrap-around secondary.

Olivier and Dunstan (66) investigated practical methods of digesting pea-blancher wastes. A mixture of equal parts of digested sewage sludge or of secondary effluent and blancher waste digested in 10 days with a 90 per cent reduction in B.O.D. The amount of blancher waste was then increased and the procedure modified until digesters fed with one part sludge to six parts waste and with waste only, both operated satisfactorily on a 9-day digestion cycle.

Gas Production

A tendency toward decreased rates of gas production in an operating plant was reported by Barrett (8). During the last year of a 10-yr. period, in which the gas produced averaged 8.3 cu. ft. per pound of volatile solids added, production reached a low of 6.3 cu. ft. per pound. The decrease was progressive over a period of five years. On the other hand, Langford (52) observed that under optimum conditions 9.5 cu. ft. of gas per pound of volatile solids can be produced. By heating raw sludge with gas burned beneath the sludge surface, Furczyk (32) noted a gas production of 12 cu. ft. per pound of volatile solids.

Digester Operation

In a case history of the Little Miami Plant, Cincinnati, Ohio, Backmeyer (5) described experiences in starting new digesters. As a result of difficulties encountered, he recommends an initial loading of not more than 0.01 lb. volatile solids per cubic foot per day. At about 8 times this loading volatile acids reached 5,000 p.p.m. in 34 days and increased during an additional 30 days to 7,000 p.p.m., despite liming. Henn (40) reported the failure of an already overloaded digester when cannery wastes were slowly released to the treatment plant from a lagoon.

Scum control by blowing digester gas into the digesting mass through holes near the bottom of old vertical heating coils was described by Kissinger (49). Injection of gas 25 to 50 per cent of the time was necessary and some increase in supernatant solids resulted.

Good compaction of secondary digester sludge in a German treatment plant by elutriation of the primary sludge was reported by Stuewer (88).

Public Health Aspects

Muller (62) noted that ascarid eggs may be generally eliminated by mesophilic digestion in the range 15° to 35° C. only if digestion is prolonged for at least six months, followed by six months of drying. Jensen (44) reported that tubercle bacilli were found in digested sludge from all of a number of plants studied in which infected persons in the contributing population were as numerous as 1 in 600.

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Sludge Disposal and Utilization

A comprehensive study (58) of British sludge disposal practice was published covering problems, treatment, dehydration, final disposal and by-products.

Sludge Concentration

At Sioux Falls (S. D.) (13) the excess activated sludge is wasted to a thickener where it is concentrated; then passed through a vibrating screen and pressure strainers and centrifuged. The centrifuges are of disc-type bowl construction with nozzle discharge of cake. One centrifuge is adequate to handle solids, from the entire plant flow of 12 m.g.d. domestic sewage and 3.5 to 4.0 m.g.d. industrial wastes. The concentrated sludge from the centrifuge is maintained at about 5.0 per cent. The volume of waste activated sludge is reduced by about 85 per cent and operating costs are given as $4.37 per ton of solids concentrated. Torpey (93) concentrated combined biological and primary sludges by controlled thickening. Full-scale tests demonstrated that activated and primary sludge can be thickened to 6 per cent solids and modified and primary sludges to 11 per cent.

Experimentation on the process of alternately freezing and thawing sludge prior to filtration have resulted in a patent (76). The resultant sludge settles more rapidly, shows better filterability and gives a high-solids cake, especially if conditioned with coagulants prior to freezing. Laboratory tests, using 1,000 p.p.m. alum, produced a cake with 34.7 per cent solids at a loading greater than 300 lb. per square foot per hour of dry solids. Coackley (22) comments on laboratory investigations on freezing sludge and reports that microscopic studies show that ice crystals fused the sludge particles together into larger aggregates; there was no evidence that cell structure is destroyed.

Beck *et al.* (9) describe an improved Büchner funnel technique for evaluating the factors involved in vacuum filtration of sewage sludge. The improvement utilizes a simple ring which is placed on the filter cake during filtration to prevent the cake from drawing away from the sides of the funnel. This technique was used in investigating such factors as degree of vacuum, ferric chloride dosages, drying time, cake thickness, elutriation, contact time with coagulant prior to filtration, mixing, sludge age and the use of acid with ferric chloride. Bargman (6), in discussing this paper, compares this technique with the filter leaf procedure commonly employed in the metallurgical and chemical industries.

Shedden (82) discusses the various aspects of filter blanket selection, installation and operation based on about 15 years of experience at the Chicago (Ill.) Sanitary District. Described are modifications to filter blanket supports for simpler and more economical blanket installation, and washing procedures, including detergent bath and inhibited hydrochloric acid washes. Experiences with cotton, wool, Vinyon, Nylon, Orlon, Dynel, and mixtures of wools and synthetics are described. Dacron, Dynel, 14 to 15 oz. treated wool and 14 to 15 oz. untreated wool (in order of decreasing economic rating) are listed as the most satisfactory materials.

A broad, general survey of some of the published literature and data from operating reports during the period 1941 to 1953 is presented by Morgan and Thomson (60). An interesting comparison of operating data and procedures and costs is made for six filter installations in the United States. Data presented indicate a slight decrease in per capita sludge production in large treatment plants but striking increases in facilities serving less than 250,000 population. Schepman (80) discusses the advantages of vacuum filtration of sludge and recommends that vacuum filters be operated with a thin cake, high vacuum, thickened feed and a permanent type of metal media.

Sludge Utilization

Continuing concern with the problem of utilizing sludge as a fertilizer was noted with particular emphasis on the availability of sludge nitrogen. Stephenson (85), discussing two methods for evaluating availability of sludge nitrogen, gives details of the test procedures and lists data obtained. He considers the soil test to be the most satisfactory method. This involves incubation of the sludge with a selected soil sample at 22° to 23° C. at 20 per cent moisture. Nitrate analyses are made for a period of several weeks on a water extract and nitrate production is compared with a standard made from dried blood mixed with the soil. Activated sludge compared favorably with dried blood but raw sludge actually depleted the natural nitrate content of the soil for about a month before a positive production was noted.

Fuller and Jourdian (31) investigated a frequently neglected aspect of the use of sewage sludge as a fertilizer; its actual effect on soil. They state that it is conceivable that the action of soil bacteria on sludge could deplete soil nitrates. Actually, the use of dried sewage sludge as a fertilizer was found not to deplete nitrates and may add some nitrates.

A pilot plant for water extraction of Vitamin B-12 from activated sludge (86) was detailed and operating data were presented.

A comprehensive report was made by Pearson (70) to the California Water Pollution Control Board on submarine outfall disposal of sewage and sludge. Considered were public health criteria, viability of sewage bacteria in sea water, survival of interic disease bacteria and indicator organisms in shellfish, effect on marine resources, mechanics of dispersion, oceanographic factors, construction and design, operation and maintenance, and sludge disposal.

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Detergents

Sheets and Malaney (83) studied the effect of synthetic detergents on the oxidation of seeded synthetic sewage using the standard dilution technique. The authors found that 2 p.p.m. of sodium lauryl sulfate doubled the B.O.D. of the sewage.

Igepon, Cyclopon and Tide (10 to 15 p.p.m.) increased the B.O.D. to 200 per cent of the control. Nekal and Santomerse showed appreciable activity only in concentrations greater than 25 p.p.m. Nonionic Tween 80 in concentrations greater than 1 p.p.m. was stimulatory to the B.O.D. organisms while nonionic Igepal was inhibitory when concentrations exceed 30 p.p.m. The cationic detergents decreased the apparent B.O.D. of the synthetic sewage. The detergent builder, tetrasodium pyrophosphate, was inhibitory in concentrations of 10 p.p.m. or more.

Bogan and Sawyer (11) studied the relationship between chemical structure and biochemical oxidation of the major commercial detergent types. They concluded that susceptibility of a synthetic detergent to biochemical oxidation was primarily dependent on the nature of the hydrophobic alkyl group and the nonionic hydrophilic polyethylene glycol group. Oxidation of the alkyl benzene sulfonate type was observed. Branching alkyl groups increased the resistance of the detergent to aerobic oxidation. Low molecular weight polyethylene glycols were readily dissimilated while the high molecular weight polyethylene glycols because of their physical characteristics were resistant to biological decomposition.

Degens, van der Zee and Kommer (26) studied the effect of certain anionic detergents on the activated sludge process on a pilot-plant scale. The authors found that Teepol (secondary alkyl sulfate) in a concentration of 50 p.p.m. active matter showed no inhibitory effect on the biological purification of sewage after a two week acclimatization period. The detergent itself was decomposed by the activated sludge. An alkyl aryl sulfonate (propylene tetramer benzene sulfonate) in concentrations of 12.5 p.p.m. and 30 p.p.m. had an inhibitory influence on the purification of settled sewage. However, 5 p.p.m. of this detergent had no harmful effect. A reduction of plant load by 25 per cent did not result in an improvement in B.O.D. or O.C. removal of settled sewage by activated sludge when 30 p.p.m. (active matter) of the alkyl aryl sulfonate was employed.

Longwell and Maniece (56) present a modified methylene blue procedure for the determination of anionic synthetic detergents in sewage.

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Reclamation

Investigation of water and sewage spreading on five permeable California agricultural soils was conducted by the University of California (17). It was found that the infiltration rate for each soil followed the same general pattern: first, an abrupt decrease in rate, attributed to dispersion of soil particles; second, an increase in rate, due to solution of entrapped gases into the percolating liquid; and third, a decrease due to accumulation of biological slimes in the soil voids. Infiltration rates in the third phase ranged from 30 ft. per day for the most permeable soil to 0.6 ft. per day for the fine soils. Application of settled sewage to soil lysimeters displayed a sharp decrease in infiltration rate due to clogging of soil surface by particulate matter. Coliform removals were generally highest in the fine soils. An increase in calcium and magnesium concentrations and a decrease in sodium and potassium concentrations in the perco-

lants were observed. Aerobic conditions existed for the first few weeks of sewage spreading after which anaerobic conditions persisted. Increase in B.O.D. in the effluents from the soils were obtained after the anaerobic stage predominated. Organic matter penetrated into the surface strata of the lysimeter soils causing a decrease in permeability and infiltration rates. Abrupt loss in hydraulic head through surface strata was experienced for all soils receiving application of sewage. The relationship between particle size characteristics of the five soils studied could not be correlated with the observed filtration rates. Therefore, field performance of a soil cannot be predicted by comparing its particle size characteristics with those of other soils for which infiltration rates have been established.

In a later report from the University of California (18), a review of the progress made in solving the problem of waste water reclamation, was presented. The factors to be considered when recharging by spreading or by injection methods are summarized. Public health, engineering and economic aspects are discussed.

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RADIOACTIVITY

Waste Treatment and Disposal

The increased industrial interest in nuclear power was evidenced by a large increase in the number of papers on the problems of radioactive waste disposal. Wolman and Gorman (146) (147) (148) reviewed the sources, characteristics and methods of disposal of radioactive wastes. The dependence of the growth of the atomic energy industry on satisfactory waste disposal methods was recognized. Various estimates of the magnitude and nature of the problem were made (12) (84) (120) (137), and much interest was shown in the sanitary engineering aspects of the atomic energy industry (29) (49) (96).

It was widely assumed that a substantial portion of American power needs will be met by nuclear energy plants, Jackson (65). Terrill, Moeller, and Ingraham (137) predicted that 90,000,000 gal. of highly radioactive fission product wastes would be pro-

duced daily in processing nuclear fuel from power reactors built during 1964 alone. Tables and curves were presented from which individual fission-product yields for reactors of any power level and operating conditions could be predicted. Straub (128) emphasized the problems of radioactive waste treatment by pointing out that the permissible limits of radioactive material in water are very low, and also that the different radioactive constituents have individual response characteristics to treatment processes.

A relatively small volume of water wastes from the processing of spent nuclear fuel contains the bulk of the radioactivity in strong acid or salt solutions. In considering the treatment of such waste for ultimate disposal by clay adsorption, Hatch *et al.* (55)(56) found that high concentrations of hydrogen, sodium, ammonium, nitrate, and fluoride ions were detrimental to the uptake of fission products by the clay. After removal of HNO_3 by distillation and separation of other nonradioactive ions by electrolysis in membrane deionization cells, the fission products were adsorbed on montmorillonite clay. The radioactive clay was then fused into glass beads for ultimate disposal. Higgins and Wymer (59) investigated a method of treating highly radioactive aluminum nitrate wastes. The Nb, Ru and Zr were removed by $Fe(OH)_3MnO_2$ scavenging with an efficiency of more than 90 per cent. The $Al(NO_3)_3$ was then converted to dibasic aluminum nitrate by destructive distillation and leached with water at 160° C. to remove Sr, Cs, and rare earths, which were separated by cation exchange for recovery. Co-precipitation methods for the removal of radioactivity from acid aluminum nitrate wastes were studied by Krieger, Kahn, and Straub (79). Ruthenium and Cs were precipitated with $Cu_2Fe(CN)_6$, Sr with $BaSO_4$, Zr and Nb with $ZrO(H_2PO_4)_2$ and the rare earths and Y with $Ce_2(C_2O_4)_3$. A removal of 95 per cent of the activity was obtained with a waste volume reduction of 20:1 at a chemical cost of 1.5 cents per l.

Walters, Weiser, and Marek (138) described a method of reducing the volume of radioactive wastes. Partial decontamination was obtained in a multicompartment permselective membrane cell followed by final decontamination in a similar cell containing a mixed-bed granular resin exchanger in the deionization compartments. The mixed-bed exchanger was regenerated by electromigration and the regenerant was evaporated for storage. Swope and Anderson (132) found that a sulfonic acid-type cation-exchange resin can remove 75 to 80 per cent of the beta-gamma activity due to intermediate levels of mixed fission products from tap water. The resin capacity for activity was more than 260,000 gal. per cu. ft. even though 6,000 gal. per cu. ft. exhausted its capacity for hardness ions. The principal radioactive elements of the effluent were Ru and Cs.

Dobbins, Edwards, and Gulevich (35) studied one- and two-stage trickling filters for treating laundry wastes containing fission products or other isotopes. Some studies were conducted on actual waste but a simulated waste was usually used which consisted of 1,250 p.p.m. citric acid, 2,600 p.p.m. HNO_3, 180 p.p.m. Igepal, 1,725 p.p.m. NaOH, 180 p.p.m. NH_4OH, and 90 p.p.m. Na_3PO_4. The 5-day B.O.D. was 500 p.p.m., the average pH 4.0, and the gross beta activity usually in the range of 800 to 1,100 d.p.m. per ml. of 200-day-old fission products, or in the order of 10^7 d.p.m. per ml. of specific isotopes. Under optimum conditions, percentage removals were: Sr, 69; Ru, 79; Zr, 79; Y, 87; Ce, 97; and fission products, 90. Experiments on the use of oxidation ponds for removing radioactivity were reported by Steel and Gloyna (124). When mixed fission products were added to 1,200- to 3,000-gal. ponds, 20 to 25 per cent of the activity was removed for each 5 days of detention in the pond. Some

smaller-scale experiments on individual isotopes were also made.

McCauley and Eliassen (93) found that radiostrontium ions can be coprecipitated with $CaCO_3$ as mixed crystals in the cold lime-soda process. Maximum reduction of calcium hardness is essential for a maximum strontium removal of 50 per cent. Repeated precipitations of $CaCO_3$ will remove more than 99 per cent of the radiostrontium.

Manowitz, Richards and Horrigan (92) described the Brookhaven National Laboratory vapor compression evaporator. The 300 gal. per hr. evaporator reduces the volume of radioactive waste to 1 to 2 per cent of the feed volume.

The radioactive waste treatment plant operation at Harwell, England, was summarized by Burns (22). The treatment consists of coagulation and fluocculation followed by effluent discharge to the Thames River at Sutton Courtenay. The British (140) dump radioactive solids contained in concrete blocks at sea. One load of 1,500 tons of material consisted of contaminated apparatus, radiocesium and radiostrontium (13). The volume of wastes from the Shippingsport power reactor will also be reduced by evaporation, according to Simpson and Shaw (119). These wastes from primary coolant, decontamination solutions, flush water, and miscellaneous waste liquid may contain up to 140 μc. per ml. The evaporator bottoms will be stored in concrete tanks. The evaporator condensate will be filtered and discharged to the Ohio River with an activity less than 10 $\mu\mu$c. per l. Fairbourne, Reid and Kramer (42) summarized the waste disposal operations at the Idaho Chemical Processing Plant. High level wastes are evaporated and stored in tanks. The low level wastes and evaporator condensate are discharged to ground through tile fields.

In order to eliminate indefinite storage of high-level (or concentrated) radioactive waste, discharge to ground was considered (139). Preliminary laboratory studies and the theoretical aspects of underground movement of radioactive waste when injected into wells were reported by Kaufmann, Orcutt, and Klein (70).

Contamination and Decontamination

A radiation survey (46) of a radium clinic showed gross surface contamination by alpha-, beta-, and gamma-emitting contaminants throughout the building and adjacent areas. Evidence of possible minor radiation injury to 6 of the 10 employees was found but uncertainty of exposure did not permit a correlation with medical findings. Hatfield (57) described the consequences of a mechanical failure in the shut-off rod system of Canada's NRX nuclear reactor. A power surge caused damage resulting in widespread fission-product contamination. Special decontamination procedures for equipment, structures and water were described.

Blasewitz and Judson (18) reported that glass fiber filters were 99.99 per cent effective in removing particulate matter (0.2 to 0.7 micron in diameter) from waste gas at the Hanford plant. Talboys and Spratt (134) evaluated laundering agents and techniques for the effective decontamination of clothing. Agents which would produce wastes amenable to biological treatment, and techniques (such as dry cleaning) which would minimize the volume of aqueous wastes, were investigated.

Surveys

Judson and Osmond (67) measured the uranium content and total radioactivity of waters from 77 localities, chiefly in the United States. Uranium values ranged from 0.02 to 460 p.p.b. The high values of both uranium and total radioactivity occurred in waters from carnotite-bearing beds in the Colorado area. Kamada (69) measured the Rn level of 116 hot springs in southern Kyushu. The maximum level found in water was 4,470 micro-

microcuries per l., and 93 contained less than 730 $\mu\mu$c. per l. The gases from hot springs were not remarkably high in radon content (0.0061 $\mu\mu$c. per l.) except for those in an active volcanic region where the radon content varied from 43,000 to 106,000 $\mu\mu$c. per l. Stehney (126) found 3–8 $\mu\mu$c. per l. each of Ra^{226} and Ra^{224} in water of Illinois wells serving a population of over 100,000. This is believed to be the highest authenticated radium content found to date in any drinking water in the U. S. Previous reports of high radium content in drinking water from Frankfurt-on-Main (Germany) and Pittsburgh, Pa., were not confirmed by Stehney.

A survey of radiation levels at 16 automatically-operated radiation monitoring stations in the vicinity of Brookhaven National Laboratory was conducted by Weiss (142). Coopey (30) measured both the numbers and radioactivity of crayfish and other crustacea in the Columbia River. There was no significant change in the biological abundance downstream from the Hanford plant, but a marked decrease in radioactivity of organisms downstream for a distance of 60 to 100 mi. Young organisms contained more radioactivity than adults and the principal isotope was P^{32}. Davis *et al.* (33) reported a radiobiological survey of the Columbia River. Near the reactors, plankton had the highest activity while further downstream insect larvae and small fish were most radioactive. Relatively high radioactivity (up to 12 μc. per kg. of scales and 0.53 μc. per kg. of flesh) was found in whitefish which had migrated from the reactor area and were caught upstream. Krumholtz (80) summarized a comprehensive ecological survey of White Oak Creek near Oak Ridge, Tennessee. Some radioactivity was found in most of the biota, the most important radioisotopes being P^{32}, Sr^{90}, and Cs^{137}.

Tanaevsky and Vassy (135) concluded, from an atmospheric radioactivity survey, that Rn accumulates during periods of calm air and is dissipated by winds. They also state that rainwater radioactivity is occasionally much higher than usual, the activity being of artificial origin.

Radioactivity from nuclear weapons tests was reported in rain in India (27), Japan (149), France (1)(47), the United Kingdom (127), and the United States (38)(39)(89)(111)(122). Particulate atmospheric radioactivity of this type was reported in the United Kingdom (127), France (47), and New Zealand (45)(114). Other reports of radioactivity from nuclear weapons came from Japan, including radioactive contamination of the fishing ship "Lucky Dragon" (118) and of its catch (74). Miyake, Sugiura, and Kameda (94) measured the horizontal and vertical distribution of radioactivity in the sea near Bikini Atoll in June, 1954.

In the comprehensive survey of the Atomic Energy Commission's monitoring program, Eisenbud and Harley (38)(39) estimated cumulated radioactive fallout as of January 1, 1955, ranging from 21 to 120 mc. per square mile or an average of 61 mc. per square mile, exclusive of Nevada. The average Sr^{90} fallout was estimated as 1 mc. per square mile. The fallout in the United States from the 1955 Nevada tests (89) ranged from 3 to 850 mc. per square mile when extrapolated to January 1, 1956. Stewart, Crooks and Fisher (127), basing their conclusions on tests of radioactivity in rain samples and in air samples taken by aircraft, stated that the total external dose in the United Kingdom from all nuclear weapons tests up to May, 1955, would reach 1.6 mr. About 70 per cent of the dose is associated with material not yet deposited on the ground. The dose due to dust suspended near ground level is negligible. They estimate an eventual dose, if the present rate of testing continues, of 26 mr. per individual. Peak air concentrations of beta activity (24-hr. averages) are usually about 2.3 $\mu\mu$c. per

cu. m., but values as high as 10 $\mu\mu$c. per cu. m. have been observed. Radioactivity originating in Nevada or in Russia was found to be soluble to the extent of 20 to 30 per cent, while that originating in Eniwetok was soluble to the extent of 55 per cent. Soule (122) reported a marked increase in the radioactivity of surface and drinking water in Massachusetts in April, 1953, and Rosenthal (110) discussed the removal of this radioactivity by water treatment plants. Coagulation and sand filtration removed 41 to 52 per cent of the radioactivity.

Effects of Nuclear Weapons

The effects of nuclear weapons, especially radiological contamination, were reported on by the Atomic Energy Commission (2), Andrews (9), Cockcroft (28), Lapp (81) and Rosenfeld *et al.* (109). List (86) correlated the meteorological trajectories of bomb debris from the 1952 Nevada tests with fallout patterns in the United States The maximum observed activity at distances over 2,000 miles was 0.83 μc. per sq. m. due to rainout. The two highest air particulate concentrations observed were 0.6 and 0.003 μc. per cu. m.

Protection against radiological contamination from nuclear weapons was described by Dunning (36), Hill (60), and the Federal Civil Defense Administration (44). The Atomic Energy Commission (4) described precautions taken to minimize fallout damage during nuclear weapons test.

The nature of fallout radioactivity was discussed by Maher (90). Iodine^{131} and Sr^{90} are the isotopes of major hazard. Sax, Gabay, Revinson, and Keisch (116) reported radiochemical analyses of Marshall Islands soil heavily contaminated after the March 1, 1954, test. Chemical procedures for Sr, Ru, Zr, and rare earths are given. There were four papers (71)(72)(73)(129) on the nature and size of the radioactive fallout on the Japanese fishing ship "Lucky Dragon." Amphlett (8) discussed the fate of radioactive contamination according to the nature of the contaminated ground. Possible treatments of contaminated land are included.

Radiochemical Methods

Rosholt (113) used the polonium daughters for the determination of sources of natural radioactivity. The alpha activity of the polonium, which was precipitated with bismuth sulfide, was measured with a scintillation counter. A combination of decay and aluminum absorption techniques permitted separate estimation of the radon^{222}, thorium^{232}, and lead^{210} contents.

Jucker and Treadwell (66), studying the coprecipitation of radium with barium sulfate, found that Ra could be quantitatively coprecipitated, and would adsorb on fresh pre-formed barium sulfate. They also found that Ra could be coprecipitated with strontium sulfate, but very poorly with calcium sulfate. Cadudal (23) determined atmospheric Rn by adsorption on active charcoal, followed by direct beta counting of the charcoal. Sensitivity was 1 $\mu\mu$c. per l. when volumes of 100 to 200 l. were used. Stehney and his co-workers (125) determined breath radon in a similar manner, except that the Rn, after adsorption, was desorbed into a proportional counter or ion chamber. For the determination of U in urine, Campbell *et al.* (24) wet-ashed and extracted with di-n-butyl orthophosphoric acid. The extract was evaporated, fused, and counted. Accuracy was reported as 84 ± 14 per cent at a level of 0.5 to 5 $\mu\mu$c. of U^{235}.

Lindner (85) compiled a number of radiochemical procedures, and Kahn (68) reported procedures for eluting various radionuclides from soil and determining them. Carter (25) gave methods in use at Harwell for separating old fission products. Strontium^{90} is separated as strontium ni-

trate from 80 per cent nitric acid; Cs^{137} by double precipitation as cobaltinitrite, perchlorate, silicotungstate, or double bismuth iodide, followed by solution in sodium hydroxide, and adsorption and elution from a cation-exchange resin; Ce is precipitated as iodate from nitric acid solution; and Ru is distilled as tetrachloride from nitric acid solution containing a suitable oxidant. Ishibashi *et al.* (63)(64) reported on the radiochemical analysis of the Bikini ashes and on paper chromatography of radioisotopes. The Bikini ashes were found to contain Ca^{45} and U^{237} in addition to fission products.

Hahn and Straub (52) gave a procedure for the determination of low concentrations of radiostrontium and radiobarium in water. The limits of sensitivity were 40 $\mu\mu$c. per l. for Sr and 100 $\mu\mu$c. per l. for Ba with a precision of about 10 per cent. Farabee (43) determined radiostrontium and radiobarium in urine. The alkaline earths were first concentrated by precipitation and then wet-ashed. After solution and adjustment of the pH to 5.5, ethylenediaminetetraacetic acid (EDTA) was added to chelate Ca and Mg, and the solution was passed through a cation-exchange column. Strontium and Ba were adsorbed along with approximately half the Mg and a small part of the Ca. The adsorbed Mg and Ca could be eluted with citric acid and EDTA at pH 5.0. Alkali metals were eluted with 0.5N HCl, after which the Sr and Ba were eluted with 6N HCl, dried, and counted.

A combination of solvent extraction and precipitation techniques was used for the separation of rare earths from Th (83). The same techniques in conjunction with oxidation-reduction were used to determine cerium (48). Two ion-exchange separations of rare earths from each other, using lactic acid elutant, were reported (32)(103). Rare earths were also separated by elution with ethanol and HCl from ion exchange columns (82), and by paper chromatography (105), using 8-hydroxyquinoline solutions.

Swain, Kreiter, and Sheppard (131) reduced water to hydrogen gas, which was then transferred to an ion chamber for determination of tritium content. Wing and Johnston (145) converted tritiated water to acetylene and transferred it, with argon, into a Geiger-Muller tube for counting.

Instrumental Methods

Schmidt (117) described the equipment used at the Chicago South District Filtration Plant for measuring radioactivity in precipitation and in raw and filtered water. The equipment includes internal proportional counters for the measurement of low activities, a Geiger-Muller tube in a flowing stream for continuous monitoring at somewhat higher levels, and battery-powered survey meters for emergency use. Weiss (142) described the instrumentation used in a survey of the Brookhaven area.

Harley and Hallden (53) gave a new graphical method for determining the maximum energy of a beta emitter and for determining impurities in beta emitters of known energy. Suttle and Libby (130) gave a method for the absolute assay of beta radioactivity in thick solids based on the observation that, under closely specified geometric conditions, beta absorption is accurately exponential, and therefore self-absorption can be described by relatively simple expressions. Pate and Yaffe (101)(102) discussed the efficiency of counting in a 4-pi counter, commonly used for primary standardization of radioisotopes.

A number of scintillation counters (31)(34)(50)(51)(78)(97)(99)(100)(144) for alpha and gamma measurements were described. Among these were a combined neutron and absolute alpha counter (50), and devices for measuring Rn in air (31) and in living animals (51). A cadmium sulfide crystal (nonscintillation) civil defense monitor was developed (77).

Three ionization chambers (41) for monitoring tritium in air and a balanced ionization chamber (104) for monitoring tritium in air in the presence of moderate amounts of gamma activity were described. Boulanger (19) used an ionization chamber to determine Rn at concentrations of 0.1 to 100 $\mu\mu$c. per l.

A chemical dosimeter for civil defense purposes, useful in the range 50 to 600 rep, was described by Taplin (136). Brooks and Ehrlich (20) discussed the applicability of the photographic film stocks in retail outlets for radiation surveys in the event of nuclear disaster.

Air Pollution

A number of samplers for air particulates were described (62)(115)(123). Heslep and Bellamy (58) discussed, in general terms, the nature and biological effects of nuclear radiation with special emphasis on airborne radioactive materials and the methods of sampling and measuring them. Waterfield (141) calculated the dosage from a cloud of fission products formed by sudden release from a stack.

Holaday (61) surveyed the Rn in American mines. Values for the individual American mines were from 70 to 59,000 $\mu\mu$c. per l. Median radon levels were 600 to 8,300 $\mu\mu$c. per l. of air, compared to about 1,000 $\mu\mu$c. per l. in European mines where a high occupational incidence of lung cancer exists. The radiation dose from 1,000 $\mu\mu$c. per l. was estimated to be 4.3 rem. per week to the lung and 72 rem. per week to the bronchi. Polonium in the urine of miners was found to vary from 2 to 38 $\mu\mu$c. per l., whereas the urine of non-miners had no polonium. Harris (54) found the radon concentration in New York State non-uranium mines varied from 10 to 110 $\mu\mu$c. per l.

Biological Effects

Whipple *et al.* (143) discussed personnel protection at the University of Rochester. The major hazards were from inhalation of both alpha- and beta-emitters. A calculation of waste discharge to stream water was also made. Albert and Arnett (5) found that the rate of elimination of thoron daughters from the human lung was insufficient to materially reduce radiation hazards, while Cember *et al.* (26) found no excess damage from inhaled particulate sulfur^{35} as barium sulfate. Kikuchi and co-workers (75)(76) described the metabolism of fission products in the case of the Japanese fishing ship "Lucky Dragon." These studies included the localization of radiostrontium, the influence of radiostrontium on blood and bone marrow, and the effects of EDTA on the metabolism of radiostrontium and radioyttrium.

A number of papers appeared on the uptake of radioactive materials from soil by plants. Two papers by Long and his co-workers (87)(88) reported on fission product uptake. Rediske and Selders (106) studied Cs uptake, and Romney, Rhoads and Larson (108) measured the uptake of Sr^{90}, Ru^{106}, Cs^{137}, and Ce^{144}. The effects of environmental factors on the uptake of Sr^{90} (98), of Ca, P and Sr (37), and of Fe (107) were reported.

Applications of Isotopes

The Atomic Energy Commission (3) summarized the distribution and utilization of isotopes over an 8-year period. A bibliography of over 7,000 items, divided into 30 categories, is included. Manov (91) stated that 2,000 institutions and 1,200 industrial firms have used radioisotopes during the past 8 years. He surveyed the applications of these isotopes and the part played by the Atomic Energy Commission and by state and Federal agencies in controlling hazards connected with their use.

Both the British at Harwell (Eng.) (10) and the Americans at Oak Ridge (Tenn.) (11) have set up research programs on the utilization of reactor wastes. Irradiation sources of Cs^{137}

(40) and of gross waste fission products (7) were considered. Rather extensive studies (6) have been made on the preservation of meat by irradiation.

The movement of water in soil has been followed (16) with a tritium tracer, and tracer techniques have also been used (112) to study fluid velocity in tubes. The destruction and stabilization of pulp wastes by irradiation appeared economically unfeasible (15). Bullen and O'Connor (21) found the radon content of Westchester County (N. Y.) sewage to be higher than that of natural waters and suggested its use to trace sewage.

Neutron radioactivation analysis was applied by Smales and Salmon (121) to the determination of quantities of Rb and Cs ranging from 10 to 0.01 μg. North Atlantic sea water was found to contain 120 p.p.b. of Rb, and 0.5 p.p.b. of Cs. Morrison and Cosgrove (95) used activation analysis for the quantitative determination of trace impurities in Si.

Regulation

A number of articles on the regulation and control of radiation appeared. Bergsma and Rechen (17) discussed the development of the control program in New Jersey. Tabershaw and Harris (133) discussed existing codes and suggested requirements of radiation control legislation. An editorial in the American Journal of Public Health (14) called for assumption by state health officials of their responsibilities in radiological protection.

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WATER NEEDS TO INCREASE 73 PER CENT BY 1975

United States water needs are expected to increase from the present daily average of 262-billion gallons to 453-billion gallons in 1975, according to recent estimates published by the Water and Sewerage Industry and Utilities Division, BDSA, Department of Commerce. Projections indicate increased water usage in the following major categories:

Category	Estimated Water Usage (billion gallons per day)	
	1955	1975
Public water supplies	17	30
Industry and miscellaneous uses	60	115
Irrigation	120	170
Steam generation	60	131

Ground water sources are estimated to be able to supply 69-billion gallons per day in 1975. The balance of the water need must be met by judicious use of surface water supplies and the conservation and use of water in industry. The report claims that by storage and regulated release it should be economically possible to provide a constant supply of water of suitable quality of 630-billion gallons daily. However, careful planning for development and allocation of water resources will be required to advance the economic development of each area and region of the United States. Competition for available water will certainly increase.

Sewage Works

BIOCHEMICAL DEGRADATION OF SYNTHETIC DETERGENTS

III. Relationships Between Biological Degradation and Froth Persistence

By Richard H. Bogan * and Clair N. Sawyer

Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

The subject of syndet induced frothing has received considerable discussion during recent years. Virtually all activated sludge type sewage treatment plants have experienced some degree of froth formation in their aeration tanks. The appearance of blankets of froth on many surface waters has been reported with increasing frequency, and on occasion this frothing has reached spectacular proportions. Although frothing may or may not be considered as evidence of the presence of synthetic detergents, it does present a rather costly and difficult to control nuisance condition for the treatment plant operator. The coating of walkways and equipment with grease laden froth creates operational hazards as well as objectionable soiling of the structures. Furthermore, widespread dispersal of sewage bacteria by windborne clouds of froth constitute a potential health hazard.

At the present time the relationship between synthetic detergents and frothing in aeration tanks and in receiving waters is not wholly understood. The over-all picture has become somewhat obscured by what appear to be conflicting opinions. It was the purpose of the research reported herein to establish information regarding the nature and some of the basic causes of frothing.

Experimental Procedure

The general procedure employed in these studies was to observe the frothing behavior of several synthetic detergents in the presence of acclimated activated sludge. Data were obtained in the form of photographic records.

Nine different molecular species or synthetic detergent types were studied (Table I). At the time of this investigation these 9 substances were representative of approximately 85 to 90 per cent of the synthetic detergents being encountered in domestic sewage (1). These materials consisted of three alkyl benzene sulfonates, three aliphatic sulfonates, and three nonionic polyoxyethylene derivatives. The alkyl benzene sulfonates differed from each other on the basis of their alkyl groupings; one had only the straight chain n-dodecyl group, another had a majority of essentially straight chain groups derived from kerosene, and the third had the highly branched propene tetramer group. The aliphatic sulfonate types studied were: (a) a sulfonated fatty acid amide, Igepon T-77; (b) a sulfonated fatty acid

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TABLE I.—Syndets Studied

System	Syndet
1	n-dodecylϕSO_3Na
2	kerylϕSO_3Na
3	tetrapropeneϕSO_3Na
4	octylphenoxy tetraethoxy ethanol
5	polyoxyethylene amide of hydrogenated tallow
6	polyoxyethylene ester of stearic acid
7	oleoyl ester of sodium isethionate
8	n-dodecyl SO_4Na
9	sodium-N-methyl-N-oleoyl taurate

ester, Igepon AP–78; and (c) pure n-dodecyl sodium sulfate. The three nonionic polyoxyethylene derivatives were octylphenoxy tetraethoxy ethanol, a hydrogenated tallow amide and a stearic acid ester of polyoxyethylene.

The activated sludges employed in this investigation were developed on a daily feeding of domestic sewage and the particular detergent under study. All sludges were subjected to a minimum acclimation period of 14 days. The exact procedure and acclimation schedule followed has been described elsewhere (2).

In preparing the activated sludges for study, each aeration system was settled for 1 hr., all possible supernatant decanted, the solids concentration adjusted, and the volume brought up to 2 l. with raw sewage 24 hr. prior to use. Subsequently, 50 mg. per liter of the appropriate synthetic detergent was added to each activated sludge. In addition, 10 mg. per liter of NH_3 nitrogen and 50 mg. per liter of Na_2HPO_4 were added for nutrients and buffer. Aeration was conducted at room temperature (25° C.) Usually 100 ml. of raw sewage were added daily to replace evaporation losses.

Experimental Results

Data are presented in Figures 1, 2, 3 and 4 which show the frothing behavior of 9 different synthetic detergents in the presence of 1,000 to 1,200 mg. per liter of activated sludge. All photographic data were taken within 5 min. of the conditions or time noted. The results relating to froth persistence have been summarized in Table II.

TABLE II.—Frothing Behavior of Activated Sludge* Containing 50 Mg. per Liter of Various Syndets

Syndet	Degree of Frothing			
	Contact Time			
	5 min.	6 hr.	21 hr.	120 hr.
Anionic				
Alkyl Benzene Sulfonates:				
Straight chain type n-dodecyl	very slight	nil	—	—
Keryl	severe	severe	moderate	slight
Branched chain type propene tetramer	severe	severe	severe	severe
Alkyl sulfate n-dodecyl	slight	nil	—	—
Sulfonated amide sodium-N-methyl-N-oleoyl taurate	strong	nil	—	—
Sulfonated esters derivative of ethyl oleate	nil	—	—	—
Nonionic				
Alkyl phenoxy polyethoxyethanol type	severe	moderate	moderate	moderate
Polyoxyethylene fatty acid amide	slight	slight	slight	nil
Polyoxyethylene fatty acid ester	slight	slight	nil	—

* Activated sludge systems contained 1,200 mg. per liter of aeration solids except in the case of the three acyclic sulfonate systems which contained 1,000 mg. per liter of solids.

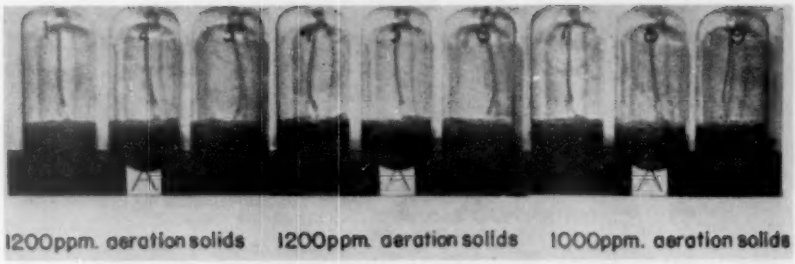

FIGURE 1.—Acclimated activated sludges before adding syndets.

In Figure 1 the 9 acclimated activated sludges are shown just before addition of the synthetic detergents. Each activated sludge had been fed approximately 1,500 ml. of raw sewage 24 hr. earlier. The aeration systems were numbered to identify the activated sludges for feeding purposes. Frothing was not in evidence.

Figure 2 shows the effect of adding 50 mg. per liter of each of the 9 different surface active agents to their respective acclimated activated sludges. Chemical constitution appears to have a marked bearing on the foaming ability of a synthetic detergent.

The three nonionic detergents (systems 4, 5 and 6) produced a rich close texture foam which was contrary to the popular belief that this type of detergent does not foam. The branched chain propene tetramer alkyl group was found to be related to the heaviest frothing among the alkyl benzene sulfonate detergents. In fact a straight chain structure appears less conducive to frothing, other things being equal. The only strong foamer among the aliphatic anionic type detergents was the sulfonated amide (system 9). This substance has been added to commercial preparations to enhance their foaming properties.

Figure 3 shows the marked effect which the addition of 25 mg. per liter of castile soap has on the frothing of synthetic detergents. The time lapse between the situation shown in Figure 2 and that depicted in Figure 3 was approximately 10 min. The effect of the castile soap persisted for approximately 1½ hr. at these aeration solids levels. Similar effects have been obtained with 200 ml. of settled raw sewage. This experiment illustrates the effectiveness of colloidal phases in

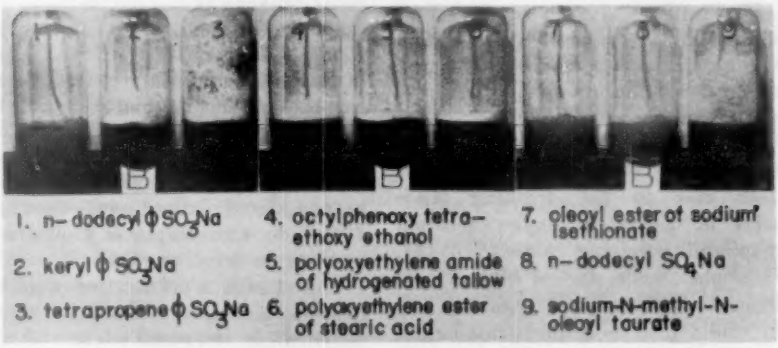
1. n–dodecyl ϕ SO_3Na
2. keryl ϕ SO_3Na
3. tetrapropene ϕ SO_3Na
4. octylphenoxy tetra–ethoxy ethanol
5. polyoxyethylene amide of hydrogenated tallow
6. polyoxyethylene ester of stearic acid
7. oleoyl ester of sodium isethionate
8. n–dodecyl SO_4Na
9. sodium-N-methyl-N-oleoyl taurate

FIGURE 2.—Acclimated activated sludges after adding 50 p.p.m. syndet.

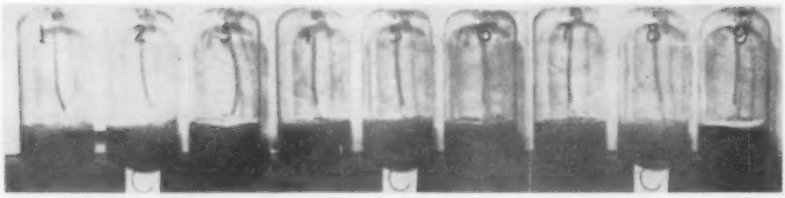

FIGURE 3.—Effect of 25 p.p.m. castile soap on syndet frothing.

tying up syndet molecules which had been present in a foam phase.

Figure 4 records the magnitude of frothing 21 hr. after the addition of synthetic detergents and again after five days aeration. Two substances, tetrapropene benzene sulfonate (system 3) and octylphenoxy tetraethoxy ethanol (system 4) appear to be extremely persistent foamers. Both keryl benzene sulfonate (system 2) and the polyoxyethylene systems (5 and 6) exhibited a lesser degree of frothing tenacity, having lost their frothing characteristics after five days aeration but not before 21 hr. The behavior of the sulfonated amide (system 9 clearly shows the short-lived frothing ability of a strong foaming readily assimilated syndet.

Discussion

Synthetic detergents are considered by many persons to play a vital part in the frothing of activated sludge sewage treatment plants and some receiving waters. Just what the exact relationship is between syndets and frothing has not been clear. Several conflicting arguments or opinions have been advanced.

It has been claimed by some that syndets play only an incidental or minor role in the frothing tendencies of activated sludge aeration tanks and receiving waters (3)(4). While plant-scale studies with certain commercial detergent preparations (3) (4) would tend to confirm this belief, it should be pointed out that the behavior of one synthetic detergent is not typical of all. The findings of this research indicate that there may be both a considerable, as well as a significant, difference between the frothing characteristics of the principal detergents.

Frothing has been considered to be largely a physical or physical-chemical phenomenon peculiar to certain surface active agents. Although large concentrations of synthetic detergents such as are employed in dish washing and laundering may foam copiously, some persons believe these substances are incapable of foaming in the dilute concentrations commonly encountered in sewage. Lynch (5) largely dispelled this concept in his studies on the behavior of dilute concentrations of commercially packaged detergents in tap water. It was shown that 50 mg. per liter of many commercial detergents are capable of excessive frothing in aerated tap water. A question still remained unanswered as to how dilute quantities of synthetic detergents behaved in sewage, or more particularly, in the presence of activated sludge. The results of the present investigation indicate that small amounts of some important syndets are capable of inducing excessive frothing in aerated activated sludge. Conversely, several synthetic detergents can be considered as ordinarily not conducive to significant or troublesome frothing in aeration tanks.

The syndet concentration normally present in ordinary domestic sewage obviously is composed of several synthetic detergents. Experimental evidence has been obtained which indi-

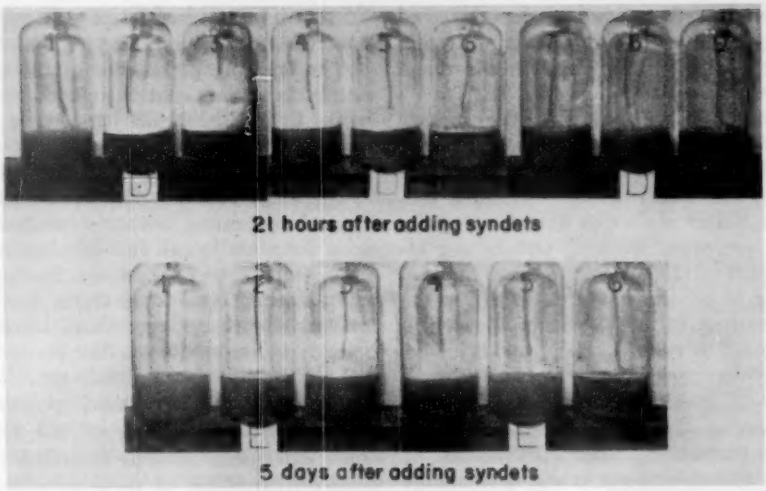

FIGURE 4.—Biological degradation and froth persistence after aeration for 21 hr. and five days, respectively.

cates that the presence of two or more commercial detergents in an aeration system frequently results in a synergistic increase in frothing tendencies (5). This could mean that an apparently poor foaming syndet may still have an opportunity to promote excessive frothing should slight amounts of strong foaming materials be present.

Reports in the literature (3)(6)(7) describe a typical pattern of frothing behavior in the activated sludge process. It has been observed that frothing is usually absent at the inlet end of aeration tanks and gradually develops toward the outlet end. McNicholas (7) makes the interesting observation that only when a treatment plant is in good condition does frothing occur. Weak sewage and low aeration solids (generally less than 1,500 mg. per liter) such as from a light load on the plant, are both conducive to excessive frothing. It was reported (6) that frothing was effectively eliminated at the Cranston, R. I. activated sludge treatment plant by operating at 3,000 to 3,500 mg. per liter of aeration solids. Many treatment plant operators have been able to mitigate frothing by increasing aeration solids. Others have been unable to do so because of physical limitations of plant facilities.

Some workers have postulated a biological basis for froth formation in aeration tanks. Gowdy (4) and Martin (8) advance the concept that the accumulation of biological oxidation products formed in the activated sludge process is primarily responsible for frothing. Syndets, themselves, are relegated to a minor or insignificant role. The production and accumulation of biological degradation residues is highly probable. However, it is rather doubtful that such substances are wholly responsible for frothing. The results of this research have disclosed two additional relationships between frothing in aeration tanks and biological processes.

Dynamic Equilibrium

Synthetic detergents present in raw sewage are largely bound up on the surfaces of suspended and colloidal impurities. This, of course, is consistent with the observation that most raw sewages have extremely poor frothing characteristics. As sewage passes

through an aeration tank its burden of suspended and colloidal organic impurities is hydrolyzed and broken down by the activated sludge. Thus a significant proportion of the surface area which originally held the surface active molecules is gradually destroyed. Some of these released surface active molecules are absorbed by the activated sludge. Others are attracted to air-liquid interfaces and appear as a foam phase. Reports in the literature (3)(6) indicate that aeration solids concentrations in excess of 2,000 mg. per liter will generally tie up sufficient surface active material to minimize the frothing tendencies of most sewages. The distribution of synthetic detergents in activated sludge is one of dynamic equilibrium as shown in Figure 5. According to this concept, a majority of the detergent molecules present in raw sewage are absorbed on sewage colloids and solids. As the sewage solids are utilized by the activated sludge for food, syndets are released and the amount in the molecular state increases. As a consequence, greater amounts are free to enter the air bubbles. Increased frothing results, unless the syndet is readily attacked biologically, in which case it passes into cell growth.

Biological Persistence

While the biological liberation of synthetic detergent molecules from the surfaces of organic impurities prepares the activated sludge for frothing, biological degradation of the syndets acts to prevent its occurrence. Thus, frothing severity is also dependent on the biological persistence of the detergents present in an aeration system. If a syndet possesses the characteristics of a strong foamer and at the same time is only sparingly susceptible to biochemical degradation, it is almost certain to be troublesome in an activated sludge system. Conversely, a readily attacked detergent molecule will have only a limited time in which to act.

The frothing persistence of the synthetic detergents studied agreed closely with their biological persistence as noted in previous studies (2). It appears that inclusion of a branched chain alkyl structure in an aromatic type detergent is not only conducive to a long biological half-life but also contributes to excessive frothing. Simple fatty acid derivatives tended to lose their frothing characteristics quickly as knowledge of their biochemical degradation would indicate. The presence of moderate-sized polyoxyethylene groups in two of the nonionic detergents studied extended the biological half-life of these substances so that their foaming ability persisted for a period in excess of 21 hr. while in contact with 1,200 mg. per liter of activated sludge.

Summary and Conclusions

The frothing behavior of 9 commonly used synthetic detergents was studied in the presence of activated sludge. The results of this investigation disclosed:

1. The frothing characteristics of a synthetic detergent are related to its chemical constitution. Furthermore,

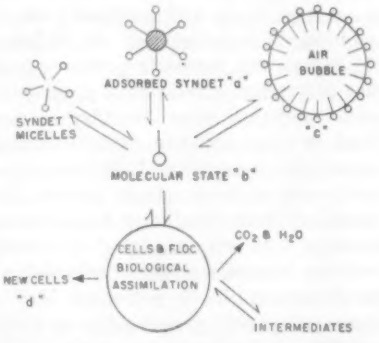

FIGURE 5.—Dynamic equilibrium of synthetic detergent surface concentrations in activated sludge.

there appears to be a considerable difference between the frothing tendencies of the several detergents.

2. Froth persistence was closely related to the susceptibility of a synthetic detergent to biological degradation. Readily assimiliated substances, such as an alkyl sulfate or a sulfonated fatty acid amide, lost their foaming ability within 6 hr. when in the presence of 1,000 mg. per liter of acclimated activated sludge. On the other hand, difficult to break down materials, such as tetrapropene benzene sulfonate, were still frothing after five days contact with activated sludge.

3. Biological liberation of synthetic detergent molecules from the surfaces of organic solids prepares the activated sludge for frothing. Colloidal aggregations, resulting from 25 mg. per liter of castile soap, effectively tied up even the strongest foamers for approximately 1½ hr. The organic solids present in raw sewage act as antifoaming agents by holding the surface active materials.

4. The presence of a branched structure alkyl group in any alkyl aryl detergent appears to be conducive to foaming, other things being equal. This fact is especially interesting when it is remembered that this type of structure is peculiarly resistant to biological degradation. The branched structure alkyl aryl detergent types were observed to be the most persistent foamers.

Acknowledgments

The investigation described herein was made possible by a grant from the National Institutes of Health, United States Public Health Service.

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CORRECTION

In the paper on "Radioactive Waste Disposal at Hanford," by Royal E. Rostenbach (THIS JOURNAL, **28**, 3, 280; Mar., 1956), an omission in the text occurs after the 15th line in the second column of page 281. After this line which reads: "met. Special laboratory facilities or" the following lines should appear:

> consulting services are needed to handle unusual or extraordinary situ-

THE WILMINGTON, DELAWARE SEWERAGE SYSTEM *

By Roy H. Ritter

Partner, Whitman, Requardt and Associates, Engineers, Baltimore, Md.

Historical Background

In 1936, due to the ever increasing pollution of the Delaware River, the states of Delaware, New Jersey, Pennsylvania and New York created the Interstate Commission on the Delaware River Basin, commonly called "Incodel," for the purpose of controlling pollution in the Delaware River. "Incodel" divided the Delaware River into zones of allowable pollution and Wilmington was placed in Zone 4 which required that the sewage from Wilmington be given only primary treatment.

In September, 1947, the Delaware State Board of Health directed the city of Wilmington to immediately take steps to install the necessary interceptors, sewers and sewage treatment plants in order to correct the pollution of the Delaware River in accordance with the terms of the Interstate Pact. In November, 1947, the Board of Directors of the Street and Sewer Department of the city of Wilmington, retained a consulting engineering firm to prepare reports, plans and specifications and to supervise construction of this project. At the time this project was undertaken 29 m.g.d. of untreated sewage was being discharged into Brandywine Creek and the Christina River. During periods of low water and drought, these waterways were essentially open sewers, offensive to sight and smell, as well as a critical hazard to health.

The existing combined sewerage system serving Wilmington discharged both sewage and storm water to the waterways. It was decided that the sewage should be intercepted by sewers paralleling the banks of the Christina River and Brandywine Creek. Rather than intercept both sewage and storm water, which would require extremely large and expensive pipes, the plan adopted would intercept only three to five times the dry weather sewage flow. The five intercepting sewer systems now discharge to one large sewage pumping station which pumps the sewage to the sewage treatment plant located on Cherry Island Marsh.

Pumping Station

Intercepted sewage flows by gravity to a common low point where it is pumped to the treatment plant. This pumping station, located on Brandywine Creek at 11th Street, is capable of pumping 160 m.g.d. It is believed the station will not have to be enlarged because the sewage flow could increase from 29 m.g.d. to 60 m.g.d. and the station could still pump 100 m.g.d. of storm water. The wet-weather pumping rate of 160 m.g.d. then would be more than two and one-half times the dry-weather pumping rate of 60 m.g.d., which is an acceptable practice for combined sewage pumping stations.

Sewage entering the pumping station passes through two channels in which vertical coarse bar screens are located. A mechanical rake lifts the collected debris from the bar screen and deposits it on a conveyor belt that

* Presented at 28th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Atlantic City, N. J.; Oct. 10–13, 1955.

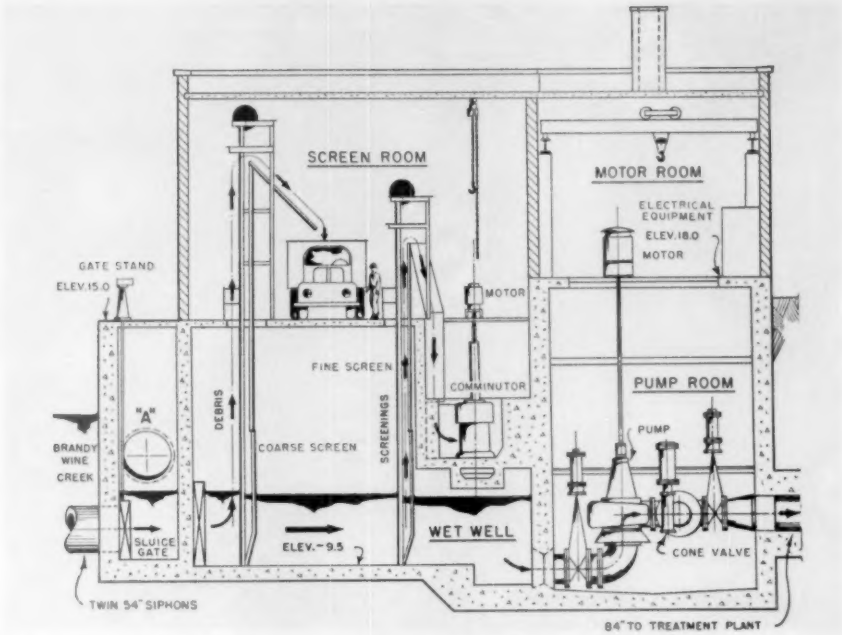

FIGURE 1.—Cross-section of 160 m.g.d. main pumping station.

discharges into a dump truck parked adjacent to the screen (Figure 1). After passing through the coarse screen, the sewage is further screened by a fine bar screen that prevents the passage of any objects larger than 1 in. in diameter. Material deposited on the fine screen is removed by a mechanical rake that discharges the collected debris into a chute leading to the comminutors. Two comminutors are provided for the shredding of material collected by the fine bar screens. After shredding, the screenings are discharged into the pump suction well.

Five two-speed vertical sewage pumps are provided in the station; each is capable of pumping 22 m.g.d. at low speed and 40 m.g.d. at high speed. Dry-weather flow varies from 20 to 50 m.g.d. and is handled by one or two pumps. To protect pumps and piping system from water hammer, cone valves are provided on the discharge side of each sewage pump. These valves close at a predetermined rate in order to prevent shock waves from forming when the pumps are stopped.

The pumps discharge into an 84-in. diameter force main that conveys the sewage to the treatment plant, located about one mile from the pumping station. A venturi meter in the force main measures the sewage pumping rate and provides a record of the daily flow.

Sewage Treatment Facilities

Fortunately, Wilmington's location adjacent to Zone 4 of the Delaware River makes it necessary to provide only primary treatment without effluent chlorination. The sewage treatment plant is located on Cherry Island Marsh (Figure 2) on land filled with material dredged from the river by the Corps of Engineers during previous

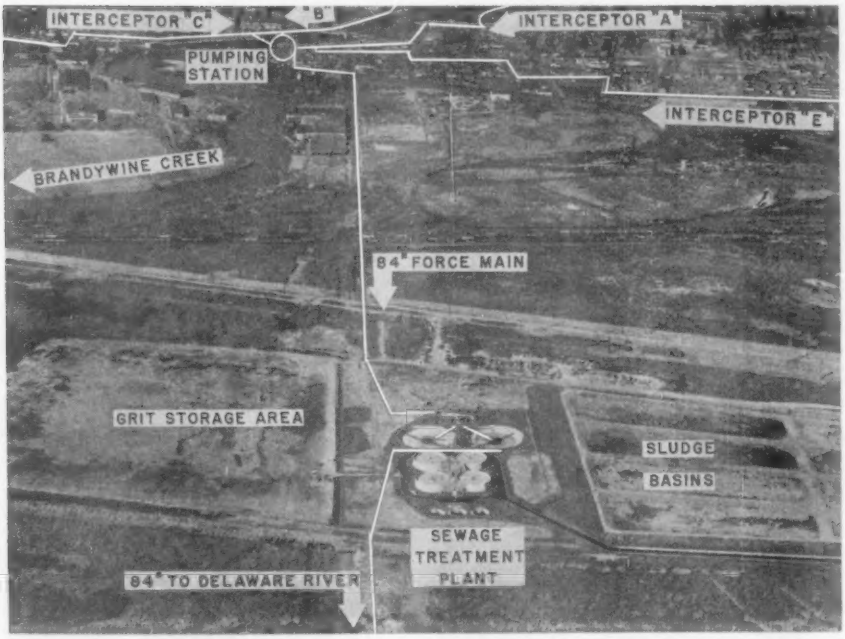

FIGURE 2.—Wilmington, Del. sewage treatment plant and interceptor system.

harbor maintenance operations. The land was readily available and inexpensive. Existing or potential habitation is located more than one-half mile from the plant site.

Treatment facilities are designed to handle 40 m.g.d. with an ultimate capacity of 60 m.g.d. The census and population equivalent figures used as a basis for design are:

Wilmington 1950 census	110,356
New Castle County 1950 census	108,523
Estimated 1955 contributing population	230,000
Design population equivalent	400,000
Ultimate design population equivalent	600,000

Grit Removal

Sewage arriving at the treatment plant contains an appreciable amount of grit which is removed in one of two 40 m.g.d. detritors. The grit is lifted by mechanical conveyors to pneumatic devices that discharge the grit on grit storage areas adjacent to the treatment plant.

Clarification

After passing through the detritors, the sewage flows to two 160-ft. diameter circular clarifiers. Surface loading rate is 1,000 gal. per square foot per day. Detention time at design flow of 20 m.g.d. each is 2.2 hr., and a maximum of 60 m.g.d. for both units can be satisfactorily handled. The unchlorinated effluent is discharged to the Delaware River through an 84-in. outfall sewer.

Elutriation

Three 40-ft. diameter elutriation tanks provide 3-hr. dentention at 4:1 dilution. The sludge is elutriated with river water to thicken it and to wash out any toxic compounds which might affect digestion. The relatively

clear wash liquid overflows to the outfall sewer, or to the clarifiers.

Digestion

The elutriated sludge is pumped into the digesters through one of four sludge heaters rated at 1,000,000 B.t.u. per hour. Four floating cover sludge digesters provide 800,000 cu. ft. of capacity or 2 cu. ft. per person. The digesters are 90 ft. in diameter with a 30-ft. side water depth. The temperature of the sludge inside the digesters is maintained at 90° to 95° F. by automatic circulation of the sludge through the sludge heaters. The digester gas is used to fire the sludge heaters.

Sludge Basins

The digested liquid sludge is pumped periodically to the large open sludge basins where it is stored and dried. The excess water is decanted and flows by gravity back to the clarifiers. The 8 basins, located on inexpensive land adjacent to the treatment plant, have sufficient capacity to hold all of the sludge produced for more than 10 years before removal will be necessary.

Operation

The treatment plant was placed in operation during March, 1955. Oil heat was used from the beginning until gas in appreciable quantities was produced after 90 days of operation. No difficulties have been experienced with any of the equipment or sludge handling. Minor problems of handling scum with an excess of hair have been encountered and studies are being made to reduce this difficulty to a minimum. The sewage flow during dry weather periods averaged 35 m.g.d.; however, during August, 1955 it averaged 54 m.g.d. due to the unprecedented wet season, including two hurricanes.

The first full month of operating data covers the month of August which is not typical but indicates the general character of the sewage and sludge. The suspended solids in the raw sewage were 265 p.p.m. and in the settled sewage 69 p.p.m., showing a removal of 74 per cent. Raw sludge solids averaged 3.3 per cent and after elutriation averaged 5.6 per cent when discharged to the digesters. The digested secondary sludge discharged to the open sludge basins averaged 9.3 per cent solids. Approximately 50,000 g.p.d. of elutriated sludge was pumped to the digesters and approximately 86,000 cu. ft. per day of gas was produced. The volatile content of the raw sludge was 61 per cent and of the digested sludge 44 per cent. The pH of the raw sludge was 7.4 and of the digested sludge 7.2.

Costs

Construction costs for the interceptor sewers, siphons and pumping station to serve the city of Wilmington and to intercept New Castle County sewage at the city limits totaled $5,335,000. The sewage treatment plant cost was $2,830,000, making the total cost of the project $12,900,000.

A summary of the costs is as follows:

Interceptors	$5,335,000
Pumping station	1,063,000
Force main	1,907,000
Underwater pipe lines	403,000
Storm drains, sewers and a 3 m.g.d. pumping station	366,000
Sewage treatment plant	2,830,000
Equipment and miscellaneous work	216,000
Engineering	620,000
Land, rights-of-way, etc.	160,000
Total	$12,900,000

Financing

In order to finance this sewage treatment program, which is the largest single project ever undertaken by the city of Wilmington, it was decided to sell general obligation serial bonds. The first bonds were sold in December, 1950, and as money was needed, additional bonds were sold at interest rates varying from 1.5 to 2.7 per cent. A total of $12,900,000 of bonds were sold; however, the excellent credit rating of the city has remained unchanged. In 1954, the assessed valua-

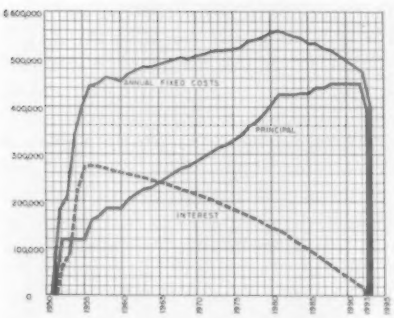

FIGURE 3.—Annual charges for the sewage treatment program.

tion of the city was $200,000,000 but a major reassessment now underway should increase this amount appreciably.

The serial maturity of the bonds of each issue was adjusted so that the combined interest and principal would increase slightly in the future. The chart (Figure 3) graphically shows the amount of principal and interest to be paid each year, and that all bonds will be paid by 1993.

Sewer Service Charge

The annual costs for this sewage treatment program are to be paid by means of a sewer service charge in proportion to the water charges rather than by an increase in the tax rate. This was made effective for the year 1951 at 25 per cent of the water bill and since 1952 at 50 per cent of the water bill. The sewer service charge is added to the water bill and both are collected in the same manner. The sewer service charges collected in 1954 amounted to $444,000. The sewerage system is being extended in the suburbs and the sale of water is increasing, so that the sewer service revenue is expected to increase in the future. During the first full year of operation, the annual operating cost is estimated to be $115,000.

The interest charges on the bonds, which became payable during the construction of this program, were paid from the revenue received from the sewer service charges rather than from bond issue funds. Although the cost of this project is considerably more than estimated in 1948, the sewer service charge of 50 per cent of the water bill suggested at that time has not been increased. The bond issues have been extended from a 30-year life, as originally contemplated, to 38 years, thereby reducing the annual fixed cost. The present minimum water charge in Wilmington is $14 per year.

The city of Wilmington has agreed to provide sewage treatment for New Castle County. Sewage meters are installed at several locations at the city limits and the Levy Court (county commissioners) of New Castle County now pays the city a sewer service charge of approximately $100,000 each year.

The presently established sewer service charges based on 50 per cent of the water bill, are as follows:

Flow (cu. ft. per quarter)	Rate [1] ($ per 1,000 cu. ft.)
0– 2,000	0.525
2,000– 5,000	0.42
5,000–20,000,000	0.385
20,000,000–50,000,000	0.24
over 50,000,000	0.10

[1] A 5 per cent discount is allowed for prompt payment.

New Castle County Sewage Treatment Program

The Levy Court of New Castle County decided to join the city of Wilmington in its program of sewage treatment and to cooperate with the Interstate Commission on the Delaware River Basin, the State Water Pollution Commission and the Delaware State Department of Health. An agreement was entered into between Wilmington and the Levy Court which provides that the city will charge the Levy Court the same sewer service charge as other customers. New Castle County will pay the total construction and operating cost of all sewers and meters at, or outside of, the city limits, and further agrees to abide by any

regulations established by the city concerning sewage treatment.

Bonds were sold as funds were needed to finance the construction of intercepting sewers, pumping stations and the force main, thus providing sewerage to the entire northern half of New Castle County. A sewer service charge was adopted by the county to finance this construction program. Because there are several water companies serving New Castle County, each with different rate schedules, it would have been unfair to use a percentage of the water bill. The present minimum water charge by all water companies is $28 per year and the Levy Court has established a minimum annual sewer service charge of $12.

The sewer service charges in the county are higher than in the city of Wilmington because the area served in the county is many times that of the area within the city limits, although their populations are about the same. The sewer service charge collected by the Levy Court in 1954 was $329,000.

New Castle County maintains all sewers and pumping stations in the county except the sewers in the city of Newark. Two sewage meters are installed at the Newark city limits and Newark pays the Levy Court for sewage in proportion to the volume passing through the meters. The city of Newark collects a sewer service charge from all properties connected to its sewer system above the two meters and its schedule of charges is the same as that of New Castle County.

The following schedule shows the sewer service charges presently applicable in New Castle County:

Flow (cu. ft. per quarter)	Rate [1] ($ per 1,000 cu. ft.)
0– 40,000	0.75
40,000– 120,000	0.675
120,000– 400,000	0.60
400,000–1,200,000	0.525
over 1,200,000	0.45

[1] A 5 per cent discount is allowed for prompt payment.

Summary and Conclusions

This sewage treatment program for Wilmington, Del. included the following notable features:

1. The city of Wilmington and the surrounding New Castle County have developed by a simple contract a well co-ordinated system of sewage treatment for an existing population of about 230,000 persons. This was done without resorting to a special authority, without using revenue bonds and without any additional or overriding governmental agencies. The Street and Sewer Department of the city of Wilmington and its engineering staff have had this contract in successful operation with the Levy Court and its engineering staff for about five years.

2. One large sewage treatment plant at about the center of population serves Wilmington and the entire northern half of New Castle County. It receives sewage from near the Pennsylvania and Maryland state lines. The city of Newark, about 12 miles from Wilmington, is also served by the system. The city of Wilmington has a combined system of sanitary and storm drains requiring the customary type of overflow regulators at the interceptors. New Castle County and the city of Newark each have a separate sanitary sewer system.

3. The installation of long intercepting sewers in the county has generated a large amount of subdivision development in areas which otherwise would not have been suitable.

4. The city and the county each obtained definite and clear-cut authorization from the Delaware state legislature to proceed with this major program to be financed by a sewer service charge in proportion to use. The legislature authorized the sale of general obligation bonds, without a referendum, which were backed by the faith and credit of the city and county in addition to the sewer service revenue. Although the bonds sold for this

project about doubled the outstanding bonded indebtedness of the city and county, the excellent (AAA) credit rating of Wilmington and New Castle County has not changed because the sewer service charges make this project self-sustaining and were considered to be equal to bonds sold for a municipal water service.

5. Wilmington and New Castle County are fortunate in that they can discharge their treated sewage effluent into Zone 4 of the Delaware River where only the minimum of sewage treatment is required. It is not necessary to chlorinate the sewage or provide secondary treatment. The Delaware River has a minimum flow during the worst drought of about 70 times the treatment plant discharge.

6. Because inexpensive land was available, digested sludge is stored in 8 large, open sludge holding basins which will provide a 10-year storage capacity before the dried sludge will have to be removed. The site is more than one-half mile from any existing or potential habitation and is located on land filled with material dredged from the river by the Corps of Engineers.

7. Elutriation of raw sludge was adopted in order to wash out any toxic material in the sludge and to concentrate the raw sludge before pumping to the digesters.

The sewage treatment program is now completed and the waterways of Wilmington are returning to their natural state of cleanliness. It is believed that the intercepting sewers and pumping station will not have to be enlarged. The sewage treatment plant is designed for a capacity of 40 m.g.d. and can be expanded readily when needed.

6,600

Memberships in the Member Associations of the Federation totaled 6,600 Active Members on December 31, 1955. Although this summation was far short of the 16,600 erroneously reported on page 360 of the March Directory Issue of the Journal, it represents a record high. The net membership increase of 499 was the greatest in the Federation's history for a year without a gain in the number of Member Associations. Unfortunately this net increase does not reveal the fact that almost 1,000 new names were added to the membership roster and approximately 500 names were removed for one cause or another. If 1,000 new members could be added each year and the losses kept to "acts of God," the 16,600 total would soon be fact instead of fiction.

Industrial Wastes

1955 INDUSTRIAL WASTES FORUM *

Prevention of Stream Pollution by the Treatment or Elimination of Wastes at Their Source

JAMES M. BROWN, JR., *Leader*

Sanitary Engineer, New Rochelle Sewage Treatment Plant, Department of Public Works, Westchester County, N. Y.

Chairman Brown:—The topic for this forum is one that is very close to my heart. I've seen a lot of situations where waste treatment at the source, or elimination of waste at the source, has meant the difference between stream pollution and clean waters.

Why Industrial Waste Treatment at the Source?

L. L. Hedgepeth, Consultant, Organic Chemicals Division, American Cyanamid Co., Bound Brook, N. J.:—My part in this panel is to outline the reasons for the problem of the abatement of industrial stream pollution through control of pollution at the source as contrasted with the treatment of the entire effluent.

The control of stream pollution in process, or at the source, is the most profitable method and, very often, the only feasible method. This is because we have many unsolved problems in industrial waste treatment. Unless certain types of waste are kept from reaching the sewer, the problem of treatment is unsolvable because there is no known method of treating some of the components. We might ask ourselves at this point why, if this statement is true (and I'm convinced that it is true) there should be any question of controlling wastes at their point of origin. I think the answer to that question lies in the human factor or in the imponderables.

Waste treatment at source is essentially a production control function, with the engineering being done by chemical engineers, the men who design the processes. They have a different concept from those of us who are trained in the public health scientific discipline. The cost sheet is their guide, whereas the protection of public health and the conservation of a natural resource are the primary objective of the public health engineer.

Keeping costs down is a legitimate objective on the part of production men as is the protection of public health and the conservation of natural resources on the part of our group. There is no insurmountable reason why those two objectives cannot be carried out simultaneously. Nevertheless, I think there is a basic conflict which is the fundamental weakness in the control of pollution at source. When an attempt is made to abate pollution by reducing it at source, then all too often the final decision is made on the basis of economics.

To cite a specific case: it would pay to clean up at source a waste liquor

* From transcript, 28th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Atlantic City, N. J.; October 10–13, 1955.

containing butanol, but because of limitations on the recovery efficiency of this machinery, this produces a butanol which is not fully refined. Refinement costs more money. Unless this is watched very carefully, the butanol will be discharged to the sewer because it is cheaper to waste it. Then if the treatment plant is not capable of handling this particular batch of waste, the receiving stream becomes polluted because the system that was set up to control pollution internally broke down. The difficulty lies in the fact that control of pollution at source is geared to costs.

It is my considered opinion that a good deal of pollution from industry can be traced back to chemical engineers with sharp pencils and slide rules, and to their cost sheets. Past experiences cause pollution control officials to be very, very suspicious when a pollution problem is to be solved internally, item by item. They know that too often it doesn't work out that way. Nevertheless, if control at source is made compulsory by management, then it usually becomes the most economical method of pollution abatement. And sometimes, the only practical method.

A large industrial plant in Virginia reduced its B.O.D. pollution from 66,000 lb. per day to 12,000 lb. per day by control at source. A good bit of capital was invested in recovery equipment. I heard $3,000,000 mentioned but I'm not sure what the total cost was. It was considerable, and represented a marginal capital investment. When that good case was published in one of our technical journals it was severely criticized by some of the elder statesmen in the stream sanitation field. They took the position that industry should have done what it did in the first place and that, since it was making money out of this method of stream pollution control, it should not have been given credit for the pollution decrease.

Now, that attitude is very unfair, and I know that the industry could have put that capital to a more profitable use. It would have meant more earnings for the industry if this money had been used to purchase production equipment.

The reduction to 12,000 lb. per day of B.O.D. improved the stream but did not restore it to a clean condition. The company showed resistance to the construction of a waste treatment plant, and my feeling is that they were wrong in taking that attitude. They were just as wrong as the critics were in criticizing what they had done previously.

Another case, this to illustrate process control. In the manufacture of acrylonitrile (vinyl cyanide) from which fibers such as orlon and acrylan are made, acrylonitrile and HCN are sewered together. There is no method that I know of for treating these wastes together. We have tried it and have had a very difficult and frustrating experience. So we made a fundamental study, along with the other people in this field with whom we exchange information, and we have reached this conclusion. We think we have sound evidence that acrylonitrile itself is not a pollutant when discharged in natural waters and kept below reasonable limits. Therefore, we feel that the solution to this waste disposal problem is to install a chemical engineering tool back in the process to separate the acrylonitrile from the HCN. If it is concentrated enough it would be sent back and processed for ultimate recovery and sale. If it is too weak to be recovered, it would be sewered direct and the HCN destroyed by the chlorination method.

Chairman Brown:—Our plan is to present a formal discussion by each panel member and, following these discussions, allow time for a brief question period.

Viewpoint of a Regulatory Authority

L. F. Oeming, Chief Engineer, State Water Resources Commission, Lan-

sing, Mich.:—I want to make it clear at the outset that I am not representing any group or cross-section of agencies. I shall attempt to give you the viewpoint of "a" regulatory authority rather than "the" regulatory point of view. Even with this qualification I may be out on thin ice because I have eight bosses, in the form of a Commission and an Executive Secretary, and on occasion they may and do have other ideas.

I have been unable to devise an explicit, concise statement that would express a typical regulatory authority viewpoint on industrial wastes. As we attempt to develop this statement, we get involved in conditions, ramifications and qualifications to such an extent that we can only approach the subject in an extremely generalized way. Consequently, I will attempt a general statement and then proceed to define briefly the circumstances that give rise to these conditions and qualifications.

My feeling is that it is preferable that control of pollution by the wastes of industry be accomplished by using the facilities provided for treatment of municipal sewage. Control of wastes at the source, followed by such pretreatment as is needed to render the wastes acceptable for final treatment and disposal, is fundamentally sound practice. I am referring to such methods as process changes, by-product manufacture, recovery and re-use, and any other methods the chemical or industrial engineer can develop.

In applying this viewpoint to a particular problem, let us first look at the advantages to industry, to the municipality and to the pollution control authority.

In industry, there are many instances in which economic benefits have been derived from waste recovery, by-product manufacture and other special methods for waste reduction. These have occurred in the paper, milk and electroplating industries to name only a few. Industry also may attain other economic benefits by avoiding a capital expenditure for waste treatment facilities in favor of an operating expense. By using the municipal facilities, industry obtains the services of an organization experienced in waste treatment and established for this purpose and thereby relieves itself of much of the burden which separate waste handling imposes. These are only a few of the many important advantages that were brought out in the detailed discussion during the Industrial Wastes Forum of this Federation in 1954 in Cincinnati. (THIS JOURNAL, **27**, 5, 587; May, 1955).

For the municipality the benefits are primarily economic although there are intangible benefits that cannot be fully evaluated. Where the wastes can be treated by the municipal utility, industry is a good cash customer and the service charges it pays are helpful in maintaining a sound financial position. The intangible benefits relate to the public relations, or good will, between industry and the municipality which is essential to good government.

From a pollution control authority standpoint, better protection usually results with fewer separate waste treatment installations. Operational supervision of waste treatment facilities on a given stream increases in complexity and difficulty as the number of separate facilities increases. Combining sewage and industrial wastes as much as possible assures more effective control as a general rule.

Among the many considerations which enter into the application of the viewpoint I have expressed are three which seem to be of primary importance. They are economic, political and engineering.

The economic considerations include an evaluation of the cost of the source control measures against the service charges for treatment at the municipal sewage treatment plant, taking into consideration the savings effected in

the charges for such treatment by reducing the strength and volume of wastes released to the sewer system. On the credit side for source control, account needs to be taken of the savings produced by a reduction in water supply charges, the value of any reduction in loss of raw material or product and the value of any by-products produced. Other factors which help determine the extent to which control or pretreatment is undertaken are the value of land on the industrial sites, the charge for maintenance and operating attention that will be required, and the cost of facilities in relation to the reduction in waste loading accomplished.

Political considerations revolve about the relationships which exist between industrial management and municipal officials. Each needs the other in arriving at a mutually satisfactory arrangement and effort should be put forth on both sides to secure an understanding of the other's point of view. On industry's side, an honest recognition of its problem and a sincere desire to reach a sound conclusion will generally elicit a sympathetic response. Sewage treatment plant superintendents are usually ready to discuss any such problems that are presented to them and to exchange information and experiences with industrial management.

Engineering considerations involve such matters as the character of the industrial plant and manufacturing process, the practicability of undertaking sewer separations to segregate wastes, the type and magnitude of the facilities required at the source and the reliability required of the controls provided. The ability of engineers, both in and outside of industry, to devise and install effective controls at the source has been amply demonstrated in a wide variety of industries. However, it also has been amply demonstrated that, after the facilities have been turned over to operating personnel, failures can and do occur due to oversight, neglect, or just plain lack of understanding of the importance of the job to be done.

It is a comparatively easy matter to bottle up wastes under an intensive program, but keeping them bottled up for any length of time is another matter. It is here that the engineer and the management need to join forces. The engineer's function is to develop the technical engineering phases while management develops the human engineering phases. The greatest emphasis should be placed on the former in order to minimize failures traceable to the human element.

This brief discussion has merely scratched the surface of an involved problem. What has been said does not apply to the wastes of many of the industries represented here today, but it is hoped that the viewpoints expressed will provide aid and comfort to those who can apply them.

The Pulp and Paper Industry

William D. Rice, Research Director, P. H. Glatfelter Company, Spring Grove, Pa.:—Wastes treatment at the source is indeed a vital part of industry's program for stream improvement and one in which pulp and paper manufacturers have made great strides.

Pulp and paper making is big business. It is the fifth largest and third most progressive industry in our economy. Per capita demand for its products has grown from 58 lb. per year in 1900 to the astounding present-day quantity of nearly 400 lb. More than 1,000 mills in 40 states produce the wide variety of paper and paper board products which totals more than 30,000,000 tons annually.

Conservation or, more specifically, the restoration and protection of water resources is a big business. Conservation is also the watch word for the pulp and paper industry because forests and waters are the industry's lifeblood. This vast industry annually consumes some 29,000,000 cords

of pulpwood. Water is used at a rate of 4,000 m.g.d. and many a gallon is used over again countless times (in recycle and re-use) before it is returned to the river or stream, lake or ocean.

Therefore, the pulp and paper industry is conservation-minded. It fosters efforts toward soil conservation and replenishes the pulpwood resources by selective cutting and reseeding which is good forestry practice in tree farming. With water it begins at the source in its many efforts to return water in kind received.

In pursuing this last and most important subject, let me speak first in terms of the experiences of the P. H. Glatfelter Co. Their efforts in this direction can be traced back many years to the earliest attempts at materials recovery, *e.g.*, surge tanks, decker savealls, and to construction in the early 1930's of lagoons for stabilization of wastes and removal from effluent waters of the most objectionable of suspended solids. Deterred only by the war years with their limitations on personnel, equipment, etc., an over-all program embracing many phases and advances has steadily gained in backing and momentum.

Industrial growth magnified the many problems as well as the incentive and, in some degree, the means to their solution. The Glatfelter plant has grown from a 1,500 lb. per day mill in 1864 to one which now produces up to 300 tons per day of book, bond, and other fine papers and 150 to 200 tons of pulps for its own consumption. Major operating departments include the pulp mill, bleach plant, de-inking plant, paper mill, power plant, filter plant and waste treatment plant. Water intake and discharge amounts to some 10 to 12 m.g.d., including turbine cooling, which is enough for a city of 50,000 people. The size and scope of these various operations have increased the economic and moral incentive to minimize waste and preserve resources.

Let us retrace a progression of developments. Surge tanks and crude savealls became a part of the first continuous paper machines early in company history. In 1895, installation of a pulp mill using the soda process introduced facilities (though crude) for recovery of cooking liquors. New paper machines in 1922 and 1930 included new designs for vats and savealls for the clarification of effluent waters. Facilities for improving conservation methods, as well as for improving product quality and quantity, were sought, weighed and applied wherever practical. Better organized research, directed toward wastes reduction, internal and external, progressed from 1930 through the early 1940's.

Following World War II, these programs blossomed to concerted action with the return of old employees, the addition of new technical personnel, and the freeing of critical materials. Consultants were also engaged to further reinforce the attack.

First launched was a thorough evaluation of effluent conditions and contributory sources in the mill. Included were comprehensive system balances and thorough sewer surveys. The basic information derived implemented a further three-pronged attack on the problems. Of equal importance were: education of operating and supervisory personnel; development and installation of many methods and facilities for internal treatment, including recovery and re-use of once wasted materials and water; and research and development toward methods and facilities for external treatment.

Much attention was given to the plant personnel in recognition of the fact that the human factor is vital to wastes reduction. The educational approach took various forms such as departmental meetings, inter-office communications, posters, articles in the company paper and most important of all an individual approach. Every effort was made to bring home the im-

portance and personal significance of waste prevention and materials and water conservation. Comparisons were drawn between material costs and items of personal expense familiar to each worker and his family. The real meaning of a small leak or a hose left running proved surprising to many.

To assist the manufacturing departments in operative control over waste, a comprehensive check system was developed and undertaken by technical personnel, to safeguard against loss at some 200 points throughout the plant. These educational and assistance programs went far to minimize neglect and to reduce mill losses and the waste treatment load.

Companion to these programs were extensive surveys and researchings toward internal improvement. In the pulp mill, enlargement and addition to recovery equipment and improvement in methods did much to tighten further those systems and reduce to a bare minimum wastes from that department. Old horizontal evaporators were replaced by a modern vertical septuple-effect evaporator system to more effectively concentrate the spent or black liquor before burning. Additional rotary furnaces were installed to provide ample capacity for burning all the black liquor. Improvements were achieved in the causticizing and lime recovery systems as a result of intensive study and perseverance. As a result of these improvements in the pulp mill, reductions of up to 50 per cent in B.O.D. loading in the total mill effluent were attained. Better segregation and separate disposal of carbon residues were also achieved, as was a marked reduction in lime sludge solids.

In the de-inking plant, revisions were obtained in washing and other operations, which resulted in a significant reduction in fiber losses, a definite economic advantage and an aid to the lessening of stream pollution.

The paper mill offered a still surprisingly fertile field, and much time and effort spent on machine saveall and over-all water systems contributed appreciable reductions in machine stock and water losses. Flotation savealls on the two large paper making machines were enlarged to provide the needed additional margin of efficiency. Improved savealls were installed in other machine systems in place of outdated Deckers and settling tanks. Over-all water systems were rearranged completely in a number of cases or rebuilt to enable maximum closure and retention of paper making materials.

Excess paper machine white waters had long been routed through a crude settling and surge system and re-used in pulping and bleaching operations. Several years of development work, together with related machine system improvements, enabled a far more effective system for segregation of the rich and lean white waters, more complete sedimentation of the richer white waters, better surge capacity for all, recovery of more solids, and more complete re-use of the now better clarified white waters in the pulp mill and bleach plant.

Many corrective measures and improvements were made to the various mill sewer systems, such as repair, renovation, new construction and segregation for best disposition.

More recently, a pulp mill and bleach plant expansion program has been completed which enabled replacement of the old rotary furnaces with a modern combustion furnace or boiler, modernization of causticizing operations and a new method in bleaching techniques. Carbon has been eliminated as a waste material, and virtually complete closure of the cooking liquor cycle is now under construction. With the addition of chlorine dioxide bleaching as the final stage in the process, it became possible to eliminate the former second or caustic extraction stage. This has eliminated a major source of highly alkaline, colored, high B.O.D. content waste.

The sum and essence of the two ap-

proaches described thus far, education and internal treatment, has been the reduction of mill solids losses and fresh water use to levels once believed to be unattainable. In 10 years, daily suspended solids losses from the mill effluent were reduced from about 25 tons to 10 tons or less. External treatment by primary sedimentation has reduced this further to a current low of approximately 2 tons. The B.O.D. quantities discharged to the stream, while materially reduced, are still cause for concern and the impetus behind a long-term study to be further implemented shortly with the installation of a pilot plant for evaluation of the activated sludge process.

These efforts reflect in part the interest and effort which has become widespread in the paper and pulp industry. Many problems remain to be solved, among them are B.O.D., color, sulfite wastes and possibly dissolved solids. Unfortunately, the various by-product developments such as vanillin, yeast, alcohol and resins afford only a limited solution, as yet. Recovery processes have been devised and are undergoing trial. However, extensive revisions in plant facilities are unfortunately most costly and out of reach of many established mills. Nonetheless, the picture is brighter by far than it was 10 or even 5 years ago, and the pulp and paper industry is conservation-minded.

Dr. Nicholas J. Lardieri, Middle Atlantic Regional Engineer, National Council for Stream Improvement, Pulp and Paper Industry, New York, N. Y.:—I understand you are treating at a very high rate. Have you observed any unusual results or effects?

Mr. Rice:—We have had unusual experience with our primary treatment works. Beginning in 1947, we ran pilot-plant operations on primary sedimentation of pulp-paper wastes, leading to design of treatment work plans. While basically these plans called for two clarifiers providing for a 2-hr. retention period, to acquire experience and ultimate best results, only one clarifier was installed initially. In addition to the usual ups and downs of a new operation, this 1-hr. retention period appeared inadequate, with carry over of solids noted.

Surprisingly, short-circuiting as such was not the cause. We found that cyclic, on-off operation of one of the large waste pumps feeding the clarifier caused repeated agitation and hence the solids carry over. The installation of an electronically controlled variable speed motor on this pump corrected this condition, resulting in a 10 to 20 per cent increase in efficiency of clarification. With the natural flocculating tendency of the wastes mixture, we are now realizing 70 to 80 per cent removal of suspended solids with a 1-hr. retention time.

The Dairy Industry

Dr. H. A. Trebler, Consulting Chemical Engineer, Baltimore, Md.:—In discussing industrial wastes I shall concentrate on dairy wastes with which I have the most experience. However, much of what can be said about dairy wastes also applies to other strong organic wastes.

Dairy products and dairy wastes contain excellent food for humans and also for a great number of microorganisms. Consequently, these wastes are probably just about the easiest wastes to treat by any of the well-known biological methods. The only difficulty, if it can be called that, is that as with any other strong organic waste, the strength must be recognized and capacity provided to handle the load. All troubles encountered in municipal plants treating dairy wastes have been due to a lack of sufficient treatment capacity. More specifically, these troubles frequently have been due to carelessness or ignorance on the part of industry in dumping excess by-products down the sewer instead of utilizing them in some way for human or animal food.

There is, however, an important economical aspect to the proper utilization of excess dairy by-products. First, the industry is highly seasonal. Two or three times as much milk is produced in the early summer flush season as in midwinter. This means that a great deal of expensive equipment must be available to handle the flush season volume, while remaining idle the rest of the year. Secondly, the prices on dairy by-products, even with government support, have been so low that it has been difficult for many processors to make a reasonable profit except for the largest and most efficient plants. The dairy industry is gradually getting accustomed to the fact that by-products manufacture is the most important waste disposal measure and that it is usually more economical to build and operate evaporating and drying equipment than to build large waste treatment plants or have expensive lawsuits because of stream pollution.

Another difficulty is that, as the prices on various dairy products fluctuate, it may become advantageous for a dairy plant to change from the production of one product to something else. Consequently, the ideal setup would be for all the processors to have equipment available to make a variety of products so that advantage could always be taken of changes in the market situation. Obviously, a compromise has to be made in order to keep the investment in equipment within reason.

Next to by-products utilization, the most important factor is waste prevention. In this field, real progress is being made through improvement in equipment design and operating methods. The bulk tank pickup of milk on the farm, instead of using 10-gal. cans, eliminates considerable waste. Also the in-place cleaning of dairy equipment and sanitary pipe lines is a great improvement over the old method of taking all equipment apart every day for cleaning. This eliminates a great deal of denting of sanitary fittings which caused dairy products to leak to the floor.

A great deal of educational work has also been done. Ultimately, the most important thing is to get plant management and employees to understand the importance of waste prevention and to obtain their full cooperation every day of the year. Excellent waste prevention and treatment manuals have been published by the Dairy Industry Committee, the Pennsylvania Association of Milk Dealers in cooperation with the Pennsylvania Health Department and also by the U. S. Public Health Service in cooperation with the Dairy Industry Committee. These manuals more or less cover the same ground, with great stress on by-product utilization, waste prevention and proper waste sampling and analysis. In other words, the information is all there, well presented, and very convincing. But it is a slow process to get the processing plants to use the information. Much remains to be done, although progress is being made every year.

As an example, in 1947 a set of standard values was prepared for the amount of waste from each process in the dairy industry. At that time it was estimated that 7 lb. of B.O.D. (equivalent to about 7 lb. of milk solids) resulted from each 10,000 lb. of milk handled in the receiving operation (dumping, weighing and can washing). The following year this value was reduced to 4 lb. Today the waste from a modern receiving station averages 1 to 2 lb. for each 10,000 lb. of milk and it is still being reduced. As a matter of fact, in many cases waste prevention has been so good and consistent that it has become unnecessary to install waste treatment facilities, and that is a big saving for a small processing plant.

Hayse H. Black, Sanitary Engineer, USPHS, Cincinnati, Ohio:—I would like to hear Dr. Trebler talk a little more about aeration.

Dr. Trebler:—I was not going to say much in detail about dairy waste disposal and particularly about aeration because this symposium stresses waste prevention. In solving any dairy waste problem, the first and most important step is to take care of by-product utilization and waste prevention. Sometimes this may be sufficient, but, if not, the first choice is to discharge the waste to a municipal sewer when one is available within a reasonable distance and a fair agreement can be made in regard to treatment costs. The next choice, where suitable land is available, is to use the waste for irrigation, either by ridge and furrow or by spraying.

Only where these methods are unavailable or prohibitive in cost should other more complex methods be considered. The choice is then between high-rate recirculating trickling filters and aeration tank treatment, with or without settling and sludge return. An efficient trickling filter installation is relatively costly to build, but cheap to operate, while aeration tanks are cheaper to install, but do require considerably more power per pound of B.O.D. removed. Since in most dairy processing plants it is particularly important to minimize capital investment, it appears that the aeration tank type of treatment is best suited under most conditions. It also requires less space and can be built close to milk processing plants without causing any nuisances due to odors and insects.

There are probably about 50 dairy waste treatment units in the United States which use biological oxidation in aeration tanks. One unit was started in 1935 so the application is not exactly new, but there has been a great increase in interest in this method of treatment during recent years.

All types of tanks are used: concrete, steel or wood; square, horizontal cylindrical or vertical cylindrical; above ground or underground; insulated, covered or open. Actually, the type of construction makes little difference except that the maintenance of a reasonably high temperature is definitely desirable and the aeration device and tank should be designed so sufficient agitation is maintained to prevent sludge settling.

It is important to have a foolproof aeration device. Recently designed waste treatment plants use steam ejectors as air-liquid mixing devices. Some use shallow tanks and simply pump the mix liquor through the ejectors and let it suck air from the atmosphere. This is simple but requires considerably more power per pound of B.O.D. removed than if both air and liquid are supplied to the ejectors under pressure.

Most units are designed for continuous flow and sludge return with about 24-hr. retention in the aeration tank and 3- to 4-hr. retention in the settling tank. A few recent installations use batch operation which simplifies the treatment plant. Unfortunately, what is saved by eliminating the settling tank probably is spent on the increased size of the aeration tank, aerators and pumping equipment. Also, the power demand is increased and comes at the wrong time of the day for most milk processing plants.

The trend has been to provide long aeration time in order to obtain maximum aerobic sludge digestion and a minimum of excess sludge to dispose of. Claims have been made that it is possible to operate these treatment plants with a sludge concentration equilibrium where new sludge is formed more or less at the same rate the old sludge is digested. In practical operation this definitely does not appear to work, at least there has not been any published data proving that it works. In all treatment plants investigated to date, sludge is lost in some way, either by actual withdrawal, or by foaming over, or as suspended matter in the effluent. As a matter of fact, foaming has been a problem in

most of these plants, especially when the sludge became overoxidized.

However, it is interesting to note that even when the effluent does contain considerable fine suspended matter, the B.O.D. reduction is excellent. Apparently, the fine suspended matter has a fairly high C.O.D., but a low B.O.D. and in most cases it may not be objectionable to discharge this to the receiving stream.

The majority of these aeration plants in the dairy industry do a remarkable job of B.O.D. removal without any odor or insect problems. The foaming problem can probably be taken care of by proper design and operation. It would be desirable to reduce the power requirements and also to find some low cost method of getting rid of the fine suspended matter in the effluent. Although aeration is neither perfect nor the only method, it serves a useful purpose.

Industrial Waste Treatment in Pennsylvania

Ralph M. Heister, Principal Sanitary Engineer, Division of Industrial Waste, Pennsylvania State Department of Health, Harrisburg, Pa.:— Today's society is becoming more conscious of its present environment and more and more positive in its demands for betterment. Our environment includes the water and air around us but this presentation will deal only with water and its industrial uses and refinements before it is discharged to Pennsylvania's lakes, streams or underground aquifers. Industry, having expansion and future growth in mind, must think in terms of using and dirtying increased quantities of water. The amount of water available for public and industrial uses remains constant. Therefore, the thinking of these two groups of users will conflict more and more, and each group will probably apply pressures and attempt to pledge the lawmakers to act according to their way of thinking. The trend of the times, nevertheless, is toward abatement of stream pollution from municipal and industrial sources. During 1955, 14 states reported legislative action to curb water pollution or promote industrial waste and sewage treatment.

At the time of passage of Pennsylvania's Stream Pollution Control Act, approved in 1937, industry did not, in many instances, have the know-how for compliance with the full requirements of the law. In such cases, applications for permits for industrial wastes treatment works were submitted to the Sanitary Water Board for works that would meet only partially the Board's requirements. Therefore, when the permits were issued, stipulations were written into them directing that experimentation and research be carried on so that practical means would be devised whereby full compliance with the Board's orders would be attained in the future.

Although many years have passed, numerous industrial waste problems are still awaiting an answer, as they pertain to high-degree treatment. My objective here is to present some of the ways by which industry has wholly or in part solved its problems by means other than (in the strict sense of the word) construction of waste treatment works. As we are all aware, industrial waste treatment works are most often the point of no economic return, especially when they are built to treat the collection of all sewered wastes. In many cases, especially at small industrial plants, this is the most practical way, but more often in large establishments, particularly integrated paper and steel mills, separate drains from various departments with separate treatment works, have resulted in pleasing premiums for the recovery of usable products far beyond the expectation of the management.

Steel Wastes

In 1947 the Bethlehem Steel Company was notified to abate its pollution

of the Lehigh River in the vicinity of Bethlehem. The stream pollution problem at this plant was caused by the shower water used to scrub the blast furnace gases. This water carried with it many fine particles of iron oxide which were considered unusable and which for years were discharged to the Lehigh River. As a consequence, a huge delta of sediment was deposited on the river bed at the outfall of the company's blast furnace sewer, and it became necessary on occasions to dredge and discard this material in order to keep the channel of the river open.

After receiving this notification, the company installed a clarification tank and other appurtenances which cost approximately $650,000. The sludges collected from this installation were concentrated on vacuum filters, partially dried, compressed to prevent the fine particles from being blown out of the stack with the furnace gases, and returned to process for reclamation of the iron ore that had been escaping as flue dust. Within 3½ months the entire project had been amortized and a saving of $43,000 per month has been effected in the reclamation of iron ore. The company then realized the amount of ore that was contained in the river and by dredging reclaimed 16,000 tons of usable ore. In July 1955, this material was valued at $9.51 per ton. Had these wastes been among those in the general mill drain, and diluted with many more millions of gallons of other waste waters, the problem would not have had so simple a solution.

Paper Mill Wastes

In many of the paper and steel mills that have expanded during the past half century, drains were convenient conveyances to the waterways and, as production increased, the wastes from a single department might flow to several different sewers, depending on which sewer was nearest to the waste-producing source.

Typical of this practice was the Johnsonburg mill of the old Castanea Paper Company, now the New York and Pennsylvania Company, Inc. At this paper mill an engineer was assigned specifically to the job of tracing all sewers. At one time, at least seven different outlets to the Clarion River existed within a short distance along one side of the mill. Imagine the job of segregating these sewers that faced this company when ordered to treat all its mill wastes, and to a high degree! The wastes at that time consisted of soda and sulfite cooking liquors, bleach wastes, de-inking wastes, whiting or filler wastes, paper mill wastes and millions of gallons of sporadically contaminated cooling water.

The company, at times of low flow, used practically all of the Clarion River and supplemented this supply by drawing from more than 100 wells along the river valley. Even then, at drought flows, production had to be curtailed in the pulping operations because of water shortages.

It need not be emphasized that the company faced a real problem. Methods for the high-degree treatment of paper mill wastes had not been developed yet. Nevertheless, strong public pressure was being directed against this company, by reason of the unsightly condition of the stream as it flowed through public parks and areas potentially suitable for recreation.

Today this paper mill has installed first-step or better treatment for all of its waste waters and also has segregated its wastes so that all unevaporated strong sulfite liquors are lagooned. All strong soda-cooking liquors are completely evaporated and sporadic discharges to cooling water drains from these sources have been almost entirely eliminated. The company has individually, and as a member of the industry, established scholarships at several universities and colleges to find more uses and therefore wider markets for evaporated sulfite liquors.

More checks on the evaporators, enabled the company to discharge, without special treatment, nearly a million gallons per day of uncontaminated cooling waters, thus reducing pumping costs and increasing the efficiency of its waste treatment works.

By relocating some sewers and diverting other polluting wastes, it was possible to isolate in one sewer almost all of the white water wastes, and to build a separate treatment unit for clarification of these wastes. In the early stages of operation of this unit, the sludges were pumped to lagoons and the clarified effluent discharged to the river. Soon, however, the sludges were gradually returned to the process of paper making and the water was utilized in process. Now more than 3 m.g.d. of water are reused and all sludges, consisting for most part of short fiber stock and filler, are returned for making paper. It is estimated that 15 to 20 tons a day of stock are reclaimed. The Paper Trade Journal in 1952 listed bleached soda and sulfite pulp as costing $140.00 per ton. The additional good water available minimized the necessity of pulp mill shutdown because of an insufficient water supply.

When the old soda mill evaporators become obsolete, an entirely new installation was made which effected a much more efficient recovery of sodium. It was also found feasible to use as fuel the black ash which previously had been lagooned and which was now crowding other installations for lagoon storage space.

One point that must be stressed in all good housekeeping programs is the need for unremitting diligence in application of good practices under the direction of an industrial waste engineer. He first must be of firm conviction that a clean stream can be attained and then that it must be maintained. Once pollution is removed, aquatic life returns and thereafter the best indicator of any recurring pollution will be dead fish. At this particular paper mill the industrial waste engineer held meetings with all supervisory personnel, made periodic inspections of various departments, and inaugurated a routine report system so that unusual discharges to the treatment works were accounted for and means devised to prevent future recurrences. This industrial waste engineer's problems are common to those of all supervisory engineers dealing with personnel. The human element must always be taken into consideration. The operators themselves must be sold on the idea of clean water and waste saving, and educated to a new way of thinking. At this mill, poster programs and educational movies were presented to employees as a reminder of the job to be done.

All paper mills in Pennsylvania have product recovery facilities of some type, depending on their method of operation. The West Virginia Pulp and Paper Company makes activated charcoal with black ash residue from soda recovery. The Hammermill Paper Company sends a large portion of its waste sulfite liquor to Robeson Process Company which manufactures synthetic tannins for the leather industry, retardants for plasters for the building trades and binders for cores and molds in the steel industry. A process change in the pulping mill at the Hammermill Paper Company's plant in Erie, Pa. holds great promise in pollution abatement if it can be proven practical. At this mill cooking liquors which contain all the carbonaceous material are now being burned in solution. The energy obtained as steam may be used to generate electricity and supplement the power needs of the mill. The inorganic residues are further refined and returned to the process cycle.

At the Downington Paper Company, a mechanically cleaned clarifier was installed on the advice of a chemist who was convinced that sufficient usable stock was being lost to warrant its installation. Management in this case

was amazed at the quantities of fiber reclaimed. Now, however, more efficient screens and recirculation within the mill have reduced fiber losses to the extent that the clarifier has been entirely eliminated.

The Beach and Arthur Paper Company at Modena has installed a mechanically cleaned settling tank for the treatment of waste white waters. Records show that 9 tons of usable pulp are recovered from this installation every day.

The Southern Kraft Division of the International Paper Company at York Haven manufactures sulfite pulp and disposes of its waste liquors by evaporation and the sale of by-products.

Pickling and Plating Wastes

The Wheatland Tube Company and the Wheatland Steel Products Company have developed a method for disposing of spent pickling liquors which may not be generally applicable, but in which these companies have had sufficient faith to invest $500,000. Treatment is accomplished by reacting the waste pickle liquor with zinc wastes from the galvanizing departments of the mills to produce ferric hydrate, zinc sulfate and chlorides. Salable materials are made from these products. The equipment needed includes crushing and screening apparatus, a rotary kiln, jacketed glass-lined reactors equipped with agitators, classifiers, rotary drum filters, monel evaporators and cooling systems.

The process converts the ferric hydrate into raw material for the manufacture of yellow and red iron pigments or abrasives to be used in paint and ink manufacture and for polishing glass surfaces. Ferric hydrate may also be used as a purifier for manufactured gas and for the production of ferric sulfate or ferric chloride. Markets for zinc sulfates are said to be limited but growing and include agricultural sprays, soil improvement, rayon manufacture, glue, electroplating, lithopone and others. Zinc chloride is used in flakes as a wood preservative and for other purposes.

The Superior Zinc Company does chromium plating. The wastes from this process contain some sulfuric acid, spent sodium dichromate and some unspent dichromate. The treatment consisits of the addition of sulfur dioxide to the wastes in order to reduce the hexavalent chromium to trivalent chromium. The mixture is neutralized with lime and the chromium precipitated as hydrated chromium oxide. After flocculation, settling and filtration, the supernatant is discharged and the sludge processed to recover metallic chromium. The soluble zinc is treated to form zinc oxide which is retreated and sold commercially.

Coal Wastes

The Lehigh Navigation Coal Company at its coal preparation plant in Tamaqua employs a froth flotation system for the separation of rock, dust, etc., from the anthracite coal silt which has been removed from the washery waste water by plain settling. The waste waters from the breaker are pumped to a mechanically cleaned primary settling tank from which the sludge or slurry is conducted to the flotation unit where the particles are thoroughly mixed with fuel oil and a small quantity of pine oil. The fuel oil adheres to the fine coal but not to the rock particles and the pine oil produces a froth on the fuel oil-coated coal. The introduction of air to the mixture carries the coal particles to the surface where they are mechanically skimmed off for drying and sale. The rock particles sink and are pumped to an abandoned strip mine for disposal. The effluent from the primary tank is passed through a secondary tank and thence to the stream. The Susquehanna Collieries Division, M. A. Hanna Company, Nanticoke also has installed a profitable froth flotation system.

Almost all anthracite coal preparation plants and many bituminous coal

plants have installed sedimentation basins for the recovery of silt, much of which is salable without further processing. In the preparation of coal for the market, water is used chiefly as an aid in the separation of the coal from rock, clay and dirt and also in separating the coal into commercial sizes. The waste water, after leaving the breaker or coal preparation plant, carries a higher percentage (sometimes as much as 5 or 10 per cent) of silt which consists of fine coal, powdered rock and clay. The average ash content is 20 to 40 per cent but the material is quite burnable in properly equipped furnaces and has been used for many years by the Pennsylvania Power and Light Company as pulverized fuel. The settling devices vary from "slush banks" or crude settling ponds to abandoned strip mines and mechanically cleaned settling tanks.

In 1953, more than 20,000,000 tons of silt were impounded and prevented from reaching Pennsylvania's waterways. This tonnage is today considered waste but tomorrow it may be utilized. Because of Pennsylvania's clean stream measures, the industry today is marketing 15 per cent of its present production in small sizes that were wasted in the past, by discharge to streams with the waste waters from the breakers.

In 1954, anthracite production was slightly more than 25,000,000 tons. Consider the huge waste that must have existed in 1917 before effective stream pollution control measures had been adopted and when the industry processed over 100 million tons. Today dredging for smaller sizes of coal is a passing industry.

Milk Wastes

The processing of milk at one time resulted in the discharge of large quantities of milk constituents such as skim milk, buttermilk and cheese whey. At one milk processing plant studied 1½ per cent of the quantity of milk handled was discharged in milk-can rinsings alone. Today many by-products, such as buttermilk and poultry feed, are recovered from these waste products. After installing entrainment separators to replace less efficient separators, a milk chocolate factory made a daily saving of 4,000 to 4,500 lb. of milk and 800 to 1,000 lb. of sugar. The raw milk intake was 800,000 to 1,000,000 lb. per day and the separators were installed to reduce pollution of the adjacent stream. Few people were more surprised (and certainly no one was more pleased) than the company management when the above facts were revealed by the plant operating records.

Future Waste Loads

In Pennsylvania, percentage reduction from established norms is still widely applicable for stream pollution abatement, except where a large industry might locate on a small or much-used stream. Another exception might be in the highly industrialized areas where even the highest degrees of treatment known for various wastes still might prove insufficient to protect the stream. As the population increases and industry expands to meet the needs of that population, more treatment of industrial and domestic wastes will necessarily have to be provided. This point may be illustrated by the steel industry, which is allowed to discharge to the stream a certain percentage of the acid used in the pickle-rinse waters. The steel industry doubled its capacity from 1945 to 1955 and therefore doubled the permissible discharges of acid. If this industry continues to expand and again doubles its production volume by 1965, we can expect four times the amount of acid discharged in 1965 as compared with that allowed in 1945.

How far back will this set us, or how many more reaches of stream will be beyond use by that time if waste treatment does not keep abreast of expansion?

It is believed that all the present

processes for treating wastes must be supplemented by more and more good housekeeping practices in order to hold the line against further degradation of our streams and maintain at least the present volume of usable water.

George A. Rhame, Sanitary Engineer, Division of Water Pollution Control, South Carolina State Board of Health, Columbia, S. C.:—It is interesting to hear these comments on the necessity of keeping up with the human element in industrial waste control operations. I remember the owners of a food processing plant who had their own waste treatment unit, and were discharging more waste than they were supposed to. One day the treatment plant operator told me that in a section where a great deal of floor washing was done, he found the trouble. One of the employees had a 1½-in. hose with which he washed down the floor. When he finished washing he just stuck the hose down in the drain and let it run. The human element always applies, I think.

Considering another phase of this industrial waste problem, we talk about industry being surprised at the amount of waste. All kinds of records are gotten up on everything possible, but I found out a long time ago that these records are filed away and in a week forgotten. They don't do any good in the files; you have to get them out and use them now and then.

The Organic Chemical Industry

A. N. Heller, Supervisor, Industrial Waste Development Section, Barrett Division, Allied Chemical & Dye Corp., New York, N. Y.:—The application of chemical engineering principles to the solution of industrial waste problems associated with the manufacture of organic chemicals presents many diverse ramifications. For example, the chemical industry produces commercially approximately 6,000 synthetic organic chemical compounds. This does not include additional organics produced from natural substances. Although it does not necessarily follow that in the production of these compounds, individual industrial waste problems result, yet the ubiquity and the complexity of the operations, *per se*, precluded a consideration of the broad field as a basis for this discussion. It was felt, however, that a presentation confined to the manufacture of three organic chemicals, the industrial waste problems resident therein and the methods of solution used, would serve, to some extent, to illustrate the primary role of chemical engineering in solving industrial waste problems of the organic chemical industry.

The three organics selected, namely synthetic phenol, natural tar acids (phenols, cresols, etc.) and "Cumar" (paracoumarone-indene resin), are manufactured at the Frankford Works of Barrett Division, Allied Chemical & Dye Corp., Philadelphia, Pa. As a point of further orientation, the Frankford Works is located on Frankford Creek which discharges into the Delaware River. At the confluence, the Delaware River acts as a tidal estuary. The intake of the Torresdale Water Treatment Plant is approximately 4.5 miles upstream from the Frankford Works. However, due to tidal effects, the discharge of industrial wastes from the Frankford Works may represent, from time to time, a factor in the quality of the Torresdale raw water intake.

In evaluating the method of attack to solve the over-all pollution problem, primary precedence was given to the abatement of the pollutants at their source. Coupled with the above was the added problem of limited space for the installation of treatment works. In addition, a study of the comparative economics of the process approach versus industrial waste treatment further emphasized the importance of applying chemical engineering principles, as the first and primary method, to solve the pollution problems of the

three organics to be discussed in this paper.

Early in 1948, a comprehensive survey of the industrial wastes discharged from the Frankford Works revealed that phenolic compounds were one of the major constituents.[1, 2] Furthermore, the industrial wastes from the synthetic phenol department (sulfonation process) was a prime contributor, and the remaining phenolics emanated from a number of departments, namely tar acid extraction and tar acid stills departments. In each of these problems a detailed process study of the unit operations established the pattern for industrial waste control, namely containment of process wastes and recovery of chemical values.

The solution of the "Cumar" problem, however, represented a basically different approach. In this case, a major change in the process permitted the essential abatement of the industrial wastes and concomitantly improved product quality.

Synthetic Phenol (Sulfonation Process)

The four major chemical reactions for this process are sulfonation, neutralization, fusion and acidification. Production of synthetic phenol from the sulfonation process involves the following eight steps:

1. Sulfonation of benzene with sulfuric acid to form benzene sulfonic acid.
2. Neutralization of the benzene sulfonic acid with sodium sulfite to form sodium benzene sulfonate, sulfur dioxide and water.
3. Fusion of the sodium benzene sulfonate with molten anhydrous caustic to form sodium phenate and sodium sulfite.
4. Puddling of the molten fusion mass in a sodium sulfite solution to produce a solution of sodium phenate and to precipitate the sodium sulfite.
5. Centrifuging of the puddled mass to separate the sodium sulfite crystals from the sodium phenate-sodium sulfite solution.
6. Acidification of the sodium phenate-sodium sulfite solution with sulfur dioxide gas (from Step 2) to convert the sodium phenate to phenol.
7. Distillation of the crude synthetic phenol to produce refined phenol.
8. Drying of the centrifuged sodium sulfite cake.

Problem Definition

All fresh water used in the process and industrial wastes discharged from the process were measured (Table I). A total fresh-water input of 17,427,000 gal. per year produced 18,408,000 gal. per year of industrial wastes. The major points of water consumption and discharge were: (a) the sulfur dioxide scrubber, (b) the centrifuge, (c) and sulfite drier scrubber and (d) the still during cleaning operations. An analysis of the various process wastes was made to determine the major constituents. Unknown by-products of the reaction were not included in this study since the data of operation experience (Table II) indicated

TABLE I. Annual Industrial Water Balance—1948

Source	Fresh Water (gal.)	Industrial Wastes (gal.)
Sulfonator scrubber	112,000	535,000
Neutralizer	420,000	0
Sulfur dioxide scrubber	1,087,000	1,705,000
Puddler	392,000	355,000
Centrifuge	1,178,000	1,190,000
Sulfite drier scrubber	12,660,000	12,883,000
Still boil-out	1,515,000	1,740,000
Steam distillation	63,000	0
Total	17,427,000	18,408,000

[1] Heller, A. N., and Wenger, M. E., "Process Engineering in Stream Pollution Abatement." THIS JOURNAL, **26**, 2, 171 (Feb., 1954).

[2] Heller, A. N., and Wenger, M. E., "Contribution of Management and Chemical Engineering to Process Waste Control." *Chem. Eng. Prog.*, **50**, 546 (1954).

TABLE II.—Industrial Wastes—1948

Source	Chemical	Quantity	
		(lb./year)	(%)
Spent sulfonator scrubber caustic	sodium hydroxide	75,000	1.6
	sodium benzene sulfonate	57,000	1.2
	sodium sulfite	355,000	7.5
Sulfur dioxide scrubber effluent	sulfur dioxide	280,000	2.0
Puddler condensate	phenol	22,000	0.7
Excess sulfite liquor	sodium sulfite	2,245,000	19.0
	sodium benzene sulfonate	150,000	1.3
	phenol	130,000	1.1
Drier scrubber effluent	sodium sulfite	705,000	0.7
	phenol	250,000	0.2
Phenol still boil-out	phenol	450,000	3.0
	other phenolics	280,000	1.9
	sodium benzene sulfonate	530,000	3.6
Total	phenol	852,000	0.55
	other phenolics	280,000	0.18
	sodium benzene sulfonate	737,000	0.48
	sodium sulfite	3,305,000	2.15
	sodium hydroxide	75,000	0.05
	sulfur dioxide	280,000	0.18

that industrial waste control required primarily a reduction in both the phenolic compounds and sodium sulfite in the process wastes.

Solution

Engineering studies determined the feasibility of recovering phenolic compounds from the process waste streams by solvent extraction. The processes evaluated indicated that economic return was minimal and that operating difficulties would probably be encountered because of the chemical characteristics of some of the process wastes. Solvent extraction, therefore, was eliminated as a feasible method for solution of the problem, and chemical and biological treatment of the industrial wastes were carefully studied. The data indicated not only an expensive operating penalty per year but considerable doubt as to expected performance.

Table II disclosed a marked similarity in the chemical characteristics of the various process wastes; Table I showed that many of the process waste streams were large in volume. It was expected, therefore, that the industrial wastes from the synthetic phenol department could be minimized by (a) reduction in volume of the wastes and (b) the recycle of the waste streams in lieu of fresh water input.

Results

The over-all effect of a study of the water balance of the sulfonation process for production of synthetic phenol is given in Table III. By 1948, the process consumed 17,427,000 gal. per year of fresh process water, none of which was recycled to the process. By 1953, the total process water demand had been reduced to 3,644,000 gal. per year, a reduction of 79.1 per cent, 2,861,000 gal. per year of this water was recycled to the process. The final

TABLE III.—Reduction in Annual Industrial Water Requirements for the Sulfonation Process

Source	1948 Volume (gal./year)			1953 Volume (gal./year)		
	Total	Recycled	Fresh	Total	Recycled	Fresh
Sulfonator scrubber	112,000	0	112,000	112,000	0	112,000
Neutralizer	420,000	0	420,000	420,000	420,000	0
Sulfur dioxide scrubber	1,087,000	0	1,087,000	0	0	0
Puddler	392,000	0	392,000	905,000	905,000	0
Centrifuge	1,178,000	0	1,178,000	1,178,000	1,128,000	50,000
Drier scrubber	12,660,000	0	12,660,000	780,000	256,000	524,000
Still boil-out	1,515,000	0	1,515,000	152,000	152,000	0
Steam distillation	63,000	0	63,000	97,000	0	97,000
Total	17,427,000	0	17,427,000	3,644,000	2,861,000	783,000

net demand is 783,000 gal. per year, which represents an over-all reduction of 95.5 per cent in the fresh water input.

The effect of reduction in fresh water demand and of recycle of process streams instead of fresh water is shown in Table IV. The industrial wastes in 1948 totaled 18,408,000 gal. per year. The volume of process streams was reduced to 3,579,000 gal. per year, a reduction of 80.5 per cent. However, 3,044,000 gal. per year of the current process streams were recycled to the synthetic phenol process instead of being discharged as industrial wastes. This left a discharge of 535,000 gal. per year, which represented an over-all reduction of 97.1 per cent in the volume of industrial wastes discharged.

The changes in chemical discharge are given in Table V. Phenol, other phenolic compounds and sulfur dioxide were completely eliminated from the process waste discharge of the synthetic phenol department. The residuum comes from the spent sulfonator scrubber caustic. The over-all reduction was 91.2 per cent.

Intensive process engineering, laboratory research and plant-scale studies of the synthetic phenol process demonstrated the importance of water balance as a primary instrument in the control of process waste. Modifications to the process resulted in an economical solution to the industrial waste problem; total costs for abatement were $100,000 but the saving in chemicals was valued at $112,000 per year.

Natural Tar Acids

The Natural Tar Acids Department at the Frankford Works occupies approximately five acres and processes a variety of inbound crudes for recovery of phenols, cresols and other tar acids.

In the extraction process the carbolic oils (originating from coal tar distillation operations performed at other plants) are washed with dilute sodium hydroxide to remove contained tar acids. The alkali-washed oils are then treated for naphthalene recovery. The carbolate resulting from the washing operation is concentrated, and partly neutralized with a flue-gas enriched with carbon dioxide. Neutralization is finished with sulfuric acid and the "sprung" phenolics layer is separated from the aqueous phase containing sodium carbonate (about 15 per cent) and dissolved tar acid (about 2 per cent). The crude tar acids are then distilled into the desired product cuts. The carbonate liquor is treated with lime to regenerate the sodium hydroxide and returned as 8 per cent plant soda after the calcium carbonate sludge is removed by sedimentation and filtration. The carbonate sludge is calcined to calcium oxide, and the

TABLE IV.—Effect of Recycling and Reduction in Fresh Water Input

Source	Volume (gal./year)			
	To Sewer 1948	Total 1953	Contained 1953	To Sewer 1953
Sulfonator scrubber	535,000	535,000	0	535,000
Neutralizer	0	0	0	0
Sulfur dioxide	1,705,000	592,000	592,000	0
Puddler	355,000	355,000	355,000	0
Centrifuge	1,190,000	1,190,000	1,190,000	0
Drier scrubber	12,883,000	572,000	572,000	0
Still boil-out	1,740,000	335,000	335,000	0
Steam distillation	0	0	0	0
Total	18,408,000	3,579,000	3,044,000	535,000

product oxide is re-used in the caustic circuit. The carbon dioxide from the calcined calcium carbonate and from the combusted fuel oil, after being cooled and cleaned of lime dust, is used for "springing" of inbound strong carbolates. Some of the excess carbon dioxide from the calcining operation is used to neutralize inbound foreign carbolates. These carbolates, however, throw the recirculating caustic system out of balance and, therefore, it is necessary to discharge excess carbonate liquor. Additional carbolates can also be processed by using direct neutralization with sulfuric acid. This produces a "sulfate liquor" which also must be discarded from the recycle system.

Problem Definition

The major industrial wastes produced from these operations are dependent on the nature of the raw materials used and the operating procedure employed. Table VI shows the volume and tar acid content of the industrial wastes produced from the natural tar acid operations.

Solution

An analysis of these data and the unit operations involved indicated the need for segregation of the more concentrated tar acid process wastes, a reduction in the volume of the more dilute wastes by better water utilization via recycle, and the installation of additional processing equipment. As a result of process modifications and segregation of concentrated process wastes, it became feasible to install a phenol (including tar acids) recovery system. Major volume reductions (Table VI) were made in the processing of carbon dioxide cleaning and cooling waters (80 per cent) and in the evaporator condensate (77 per cent). Furthermore, the 173,000,000 gal. of dilute wastes which averaged 80 p.p.m. of phenolics were not included in sizing a dephenolizer and are under investigation as a separate entity.

Based on the data presented in Table VI a dephenolizer was designed to process 25,000,000 gal. per year (54 g.p.m.) of waste containing 8,300 p.p.m. of phenolics. The basis of design included, in addition to the wastes from the natural tar acid department

TABLE V.—Reduction in Quantity of Chemicals Discharged

Chemical	Quantity (lb./year)		Reduction (%)
	1948	1953	
Phenol	852,000	0	100.0
Other phenolics	280,000	0	100.0
Sodium benzene sulfonate	737,000	57,000	92.3
Sodium sulfite	3,305,000	355,000	89.3
Sodium hydroxide	75,000	75,000	0.0
Sulfur dioxide	280,000	0	100.0
Total	5,529,000	487,000	91.2

TABLE VI.—Reduction in the Waste Volume and Tar Acid Content for the Natural Tar Acid Operations

Source	1948			1952[1]		
	Wastes (gal./year)	Tar Acids		Wastes (gal./year)	Tar Acids	
		(lb./year)	(p.p.m.)		(lb./year)	(p.p.m.)
Carbon dioxide cleaning and cooling waters	15,000,000	40,000	320	3,000,000	40,000	1,600
Excess carbonate liquor	2,000,000	348,000	21,700	2,000,000	348,000	21,700
Evaporator condensates	23,250,000	175,000	910	5,250,000	175,000	4,000
Boil-outs	975,000	89,500	11,000	400,000	89,500	27,000
Miscellaneous	173,000,000	115,000	80	1,530,000	23,000	1,800
Total	214,225,000[2]	767,500	430	12,180,000[3]	675,500	6,750

[1] 173,000,000 gal. of waste containing 115,000 lb. of phenolics (80 p.p.m.) was not included as part of the recovery program.
[2] 400 g.p.m.
[3] 23 g.p.m.

(23 g.p.m.), the expected phenolic wastes from the new cumene-phenol plant and also a reserve capacity for plant expansion and process changes.

The operation of this dephenolizer during 1954 and 1955 at a level of 95 per cent efficiency has confirmed the basic design assumptions. Currently the dephenolized waste is discharged at a controlled rate to the Northeast Sewage Treatment Works, Philadelphia.

Again the application of chemical engineering principles permitted not only the effective control of an industrial waste at its source, but also reduced markedly the size and thereby the cost of installing recovery facilities. The total cost of the project was estimated at $635,000. The cost of industrial waste control for the Natural Tar Acid Department has been operating at slightly better than break-even.

Paracourmarone-indene Resin

Problem Definition

In the manufacture of paracourmarone-indene resin (Cumar), high-flash fractions from carbolic and drip-oil distillation are first washed with dilute alkali to remove tar acids and dilute acid to remove tar bases in preparation for use in the polymerization unit. Concentrated sulfuric acid was used at low temperatures and the resultant acid-sludge layer became a major industrial waste requiring disposition. In addition, the polymer product was neutralized with caustic and washed with water prior to distillation for recovery of light ends and preparation of finished specification resins from the kettle.

From this operation approximately 115,000 gal. of sulfuric acid sludge and 1,000,000 gal. of soda sludges were produced each year. In order to abate stream pollution, the acid sludges were processed in an acid recovery plant at an expense in excess of the value of material recovered. However, other industrial wastes of greater volume than the original sludge resulted and at best only a partial solution to the acid sludge problem was effected. In addition, all of the soda sludges (including 85,000 gal. per year of useful oils) were discharged to Frankford Creek.

Solution

The substitution of boron tri-fluoride for sulfuric acid as a catalyst in

the polymerization step has eliminated the formation of both acid and soda sludges. The only residual industrial waste is a small unrecycled boron trifluoride stream which is neutralized prior to discharge.

Although this major process change was motivated by industrial waste control objectives, other benefits have resulted, including an improved recovery of resins and solvents, a reduction in catalyst cost, and the elimination of various process difficulties. In addition, an improvement in product quality has also been effected. The total cost was $237,000.

Dr. I. S. Wilson, Monsanto Chemical Co., Ltd., Denbighshire, North Wales, Eng.:—We have been engaged for quite a number of years in the treatment of mixed organic wastes from a number of synthetic organic chemical processes, such as synthetic phenol production by the sulfonation process. We have had wastes from silicon hydrate and quite a range of chemicals. We have had a considerable job in cleaning up this waste and have installed complete chemical treatment. We have been greatly encouraged by the results of this treatment.

Our operating conditions are quite different from those of Dow, and I don't think we are as well advanced in the line of aeration as they are. We have not used aeration treatment in our plants so far; although we did contemplate using filters for first-stage treatment. We've done quite a bit of work on the chemical treatment process, but we still think that our ideas are capable of being improved, and I'm in this country to obtain information from the work that has been done on various modifications of the old aeration principles. We mix organic wastes together and treat them chemically, and have obtained fair destructions, probably about 75 per cent. However, we believe that we can get 95 per cent destruction with the complex mixture of wastes that we have now.

We are enthusiasts on both the chemical and aeration methods of treating organic wastes, and we think they have possibilities which have not been thoroughly explored as yet. I'm quite prepared to see further developments along this line. That's roughly what we're doing in my own country. I have been touring some of the company plants in the United States and I have visited a lot of interesting waste treatment plants but I think that probably the need for rehabilitation does not exist to the same extent here as it does in England. English streams are much smaller and the requirements for water are greater, but the task must be done.

Jack T. Garrett, Industrial Hygienist, Monsanto Chemical Co., St. Louis, Mo.:—I am interested in the thinking of industry on the direct incineration of small volumes of highly concentrated aqueous wastes. We have done some work in this field, and found that it is the system which offers the best solution to some of our most trying problems.

Mr. Hedgepeth:—I'm afraid that your experience exceeds ours. We do not directly incinerate liquid organic wastes in equipment especially provided for that purpose. When we get some waste which is burnable and might cause trouble, we have been using a ditch that we open up, dump our waste in, add some paper or combustible refuse and then safely ignite it. It is a crude method but it works, and the safety department approves it. We have no incinerators or mechanical equipment, to my knowledge.

Mr. Garrett:—I'm not discussing directly combustible material, I'm talking about materials that are combustible organics in concentration of, say, 500 p.p.m. in water. I grant you that it is not a procedure that ordinarily is undertaken, but in many cases it is a good procedure, and we have seen it work.

Mr. Heller:—Before I comment, I'd like to ask one question. In the in-

cineration of the waste waters, do you try to recover any of the heat value?

Mr. Garrett:—We would like to in some cases; unfortunately this can't be done in the particular case I'm interested in. I was wondering if anyone has had any experience with the same process. You can imagine the heat necessary to raise the organic materials plus this terrific amount of water to the temperature necessary for incineration.

Mr. Heller:—The one problem that arises when you consider this method of approach is, are you creating an air pollution problem by simply shifting the point of pollution?

Mr. Garrett:—In many cases this might be true. It depends largely on what you're burning. I'll grant you we're talking about a field that involves several thousand products. I'm particularly interested right now in the burning of phenolic wastes; this, by the way, is in a plant that utilizes phenol. We realize, of course, that it will create an air pollution problem if the combustion is not properly carried out and the exhaust gases are not watched. We have taken that into consideration, but what I want to hear is some experience with the actual burning of aqueous organic wastes that do not contain any material that is directly toxic in an air pollution sense.

Mr. Heller:—Our experience along those lines is very limited. We have considered that approach, either by using direct incineration, or the use of a catalyst which would permit the destruction of the organics at a lower temperature. If the organic content is high enough in the waste stream, there's enough driving force in terms of B.t.u. input to maintain the catalytic performance without additional heat. It will require, obviously, a recovery system. But the point that always comes to my mind in considering this kind of a process, is what are the comparative economics, in terms of recovery of phenols from the waste material versus the cost of destroying them by incineration? The latter is always an out-of-pocket cost, which is rather difficult to control operationwise.

R. W. Haywood, Jr., Sanitary Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del.:—The incineration of organic wastes has been investigated and applied in the gaseous stage by Dr. Verne Moses at the Bell Works of du Pont. Mr. Garrett might be interested in the salvo process, which is under development. I'm not sure there has been any plant-scale application of this process that involves really low organic content liquid at extremely high temperatures and pressures. We've looked into it but feel that its cost is prohibitive as far as we're concerned.

Every time we talk industrial waste, we frequently say, "Well, it's going to cost a tremendous amount of money." I'm sure management invariably will think of that. I'd like to sort of back into a possible savings aspect. I think within the next decade there will be very few companies who won't be forced to spend money on waste treatment. And, assuming that this money will have to be spent, savings can be effected by the proper study and evaluation of the over-all problems.

I'd like to cite an example. Ten years ago, when this problem was first forced on the management of two plants located adjacently, treatment processes which would have been effective would have had a combined cost of $800,000 to $1,000,000. Logically, as might have been expected, management was most reluctant to spend that kind of money, and so the problem dragged on. Increased pressure was applied until eventually detailed studies were made of the problem. The means were found, through process changes and good housekeeping, which have resulted in a major reduction in the B.O.D. load. The load reduction

and different methods of treatment have resulted in savings in investments of some $600,000.

Now, you may say that's a poor saving, but I feel that the $600,000 that the company has not been forced to spend and could use for additional production facilities, represents a savings. I think one of the problems that we industrial waste engineers have is selling management on the need, the absolute necessity, for waste treatment. I think the Manufacturing Chemists Association is doing a wonderful job through their regional committees in discussing these various problems. I'm sure that it is going to be productive of a great deal of better understanding on the part of management, and as a result industrial waste pollution abatement will go forward at a much more rapid rate.

Chairman Brown:—I'd like to repeat a remark that Mr. Heister made. He said that the money spent at the sewage treatment plant should be spent to treat wastes that have no other economical return. In other words, it doesn't pay to treat them anywhere else but in a sewage plant, and I think that is important. My experience, at least, has shown that quite often it is the job of the sanitary engineer to make sure that the sewage treatment plant is not being used as an easy method to get rid of some of industry's manufacturing problems by putting material in the sewer which should go elsewhere.

From the Floor:—In our plants in Pennsylvania and Virginia we make vitamins and cortisone. We have a lot of small waste streams discharging less than 1,000 g.p.d. These wastes have extremely high B.O.D. values and are quite toxic to any type of biological treatment. We have found that the cleanest and best way of getting rid of these is to burn them. However, the costs are extremely high from the standpoint of maintenance. Some of these wastes contain corrosive materials; accordingly, incinerator maintenance cost is extremely high. The metal work is continually corroding and some of the firebrick is disintegrating, so that once or twice a year the incinerators must be completely re-lined. We have tried other means of disposal, such as biological treatment; however the efficiency of the filters immediately drops. Actually, we would like to find some better method of getting rid of this type of material.

Mr. Heister:—At the Hammermill Paper Company, Erie, Pa., experimental work has been carried out with the Zimmerman process as it is called. Not too much information has been released on it as yet, although in talking to Dr. Jackson, he sounded discouraged because of the high cost. This method pre-heats both the air to be used in oxidation and the waste liquid itself, in combination with very high pressures. The steam generated by oxidation of carbonaceous materials is then converted into electric energy, and the non-combustible inorganic chemicals are reclaimed for re-use in process. It seemed to have great promise at first, and the company officials were quite enthusiastic. However, until more of the kinks are ironed out to reduce the cost, it doesn't seem to be practical at this time. I still look forward to this process as the next step in the oxidation of those wastes that might be concentrated, especially the lignins contained in the pulp mill waste waters. These wastes are very much of a problem in coloring the streams, and destroying their esthetic value.

Mr. Black:—My comments must necessarily be confined to observations, but I would like to emphasize what Mr. Garrett has said regarding incineration. I presume most of you are familiar with the new incineration unit that was placed in operation by Imperial Oil Limited, Sarnia, Ontario, Canada. It seems to be doing a marvelous job; and although it is expen-

sive, it is getting rid of some concentrated organic wastes. One of the points that I should like to make is that we really need improved type incinerators for handling highly concentrated toxic wastes. Some will advocate the disposal of these wastes by lagooning or by injecting into underground formations. It should be possible to control air pollution from an incinerator about as well as we prevent ground water contamination. I would like to go on record as encouraging further exploration of this use of incineration.

Mr. Garrett:—The only real way to burn these organic aqueous wastes, I presume, is to produce by-product materials that are not toxic themselves. This is really what motivated our initial interest in incineration. We finally rigged up a peculiar looking apparatus in the laboratory. It was an incinerator model, to find out whether or not, concentrated aqueous wastes could be destroyed and what temperature levels were necessary. We found, in running this incinerator, that in the presence of excess air, with the air pre-heated to the temperature that we thought was necessary, we could destroy the cyanide ion in particular, and also some organic nitriles.

To our amazement we learned that if a source of ignition is introduced, such as in a gas furnace, this source of ignition would lower the necessary operating temperature. The high heat required was one of the reasons that we were not too enthused earlier on securing oxidation in this manner. Using an ignition source, we designed an incinerator to destroy several different wastes. We did not know whether it was going to work and a considerable amount of money was invested. Fortunately it works fine. However, that was not the particular problem that I had in mind.

I think we should explore the incineration of aqueous wastes for the destruction of material in a plant that cannot afford extensive treatment facilities or has a shortage of available space. The major difficulty at present is the cost for heat and maintenance. It is certainly something worth studying, because in our case it works exclusively and further work might make it more economically attractive.

Gerson Chanin, Chief Sanitary Chemist, East Bay Municipal Utility District, Oakland, Calif.:—The East Bay Municipal Utility District is concerned with the sewage disposal facilities for six cities located along the east shores of San Francisco Bay. A large variety of industry is located along the 21 miles of shoreline.

I would like to make several points. There hasn't been very much said about industrial waste problems as viewed by the treatment plant operator. Personally, I feel that in many municipal treatment facilities there is room to handle a certain amount of industrial waste from a variety of industries. In the preparation of ordinances necessary for the proper operation of sewage treatment plants, the following points are generally considered in setting standards for the discharge of waste material to the sewers.

1. The possibility of damage to the structures.

2. The possibility of increased cost of sewage treatment, due to some unusual waste.

3. The possibility of creating a dangerous and hazardous condition in the sewer or the sewage treatment plant, either by the presence of explosive or combustible gases, or some toxic material that might be detrimental to the health of employees either on inhalation or contact.

4. Sewage treatment plants are now being regulated by various governmental agencies and their effluents must meet certain requirements. Therefore, wastes which cannot be treated and satisfactorily discharged to the receiving waters must be regulated.

However, within these regulations it is still possible to handle a variety of wastes; and actually, in some cases, it is often the only way to dispose of certain types of wastes. For example, cannery wastes may be more effectively handled when mixed with domestic sewage, because these wastes by themselves generally are deficient in the nitrogen and phosphorus necessary to support life in a biological treatment unit.

Just by way of example as to what can happen, the area we serve contains 10 fairly large canneries. They operate only three to four months per year. Prior to the establishment of sewage treatment, the only regulation for the canneries was one set by the State Fish and Game Department which required screening of the waste so that solids which might affect fish would not get into San Francisco Bay. Then, the sewage treatment plant was constructed and the canners said, "Now we have sewage treatment; let's throw it all into the sewer." We called a meeting of the canners and pointed out to them, that it was anticipated that approximately 50 tons of solids per day would be removed from the sewage collected in the entire district and this amount would be handled by the digestion facilities at the sewage treatment plant. It was further pointed out that the canneries could discharge almost 800 tons of waste solids per day if all wastes were discharged into the sewer, making it absolutely necessary for the canners to continue to screen their wastes, even though sewage treatment would be available. Complete cooperation was obtained. The B.O.D. in the waste-sewage mixture was not high enough to adversely affect the sewage treatment plant processes.

Also, we have developed a relatively large laboratory staff at the sewage treatment plant; one of the primary purposes being to serve industry with some degree of technical assistance in solving their waste problems. We consider industry as much a part of the public as the individual citizen. When it comes to our attention that a certain waste is giving difficulty, we do not just go to the industry and say, "You have a problem; do something about it." Rather, we go to the industry, contact management and explain to them why there is a problem. Very often industry and sewage treatment plant officials don't talk the same language, resulting in misunderstandings. For example, industrialists are accustomed to thinking of waste materials in percentages, while treatment plant personnel think in terms of parts per million, the latter might be of importance from the standpoint of waste treatment but not from the standpoint of a materials loss. Quite some time is spent in describing the nature of the problem, what the ill-effects are, and then our services are offered to determine the quality of the waste and the extent of the problem. In this way industry knows what is desired in the way of waste pretreatment. This is good public relations and results in good cooperation between our staff and industry.

Dr. R. W. Hess, Coordinator of Pollution Research, Allied Chemical & Dye Corp., National Aniline Division, Buffalo, N. Y.:—There is not much I might add, but I think the point that has been made about the engineering approach is that it is a matter of reviewing all the possibilities as to whether the problem should be attacked in the light of the incineration process, recovery of waste products, or treatment, which may include putting the wastes in the municipal sewer. The sanitary engineer might approach the problem more as a matter of treatment only. I think the chemical engineering approach involves considering the biological treatment which may eventually be the most economical solution but first, all methods must be considered.

Chairman Brown:—I know that the paper industry must be like many other industries that have a great deal of variation in flows and in the amount of product that is produced. I'm wondering how a waste treatment plant such as has been described would stand up under wide variations in operation.

Mr. Rice:—There are quite wide variations among process operations in the pulp and paper industry. At the same time, we have made considerable strides in leveling out so that we have a fairly well-balanced system. However, we do encounter change-off and shut-down conditions. In many instances, facilities are provided to temporarily contain excesses which are then worked away gradually either in normal recovery systems or to the waste treatment plant. In this regard, the problem seems never completely solved, and is a matter for continuing attention.

Chairman Brown:—We have to get down to operation, and I don't mean only waste treatment plant operation; I mean the manufacturing operation, up in the production area. Manufacturing personnel have to be taught to appreciate the effect lime, acid, phosphate, grease, or anything else has on the sewage treatment process. So it seems to me that we all have to do a public relations job, not only with the officials in industry but also with the production man, the man who turns the valve. You have to get him to realize that the sewage treatment plant is not a place to dump all the waste he produces, but instead you must get him to decide intelligently what wastes can be disposed of best elsewhere.

Some work was done at American Cyanamid Company along these lines. A company magazine is sent to everybody in the plant. Management realized the necessity of letting the fellow who turns the valve in the production area know what happens at the other end of the waste line. The company did a good job in presenting an article dedicated to the industrial waste treatment plant. Pictures were taken, not only of the superintendent, but of the man who shoveled sludge from the drying beds and the men who operated the plant. People who worked in the manufacturing plant looked at those pictures and read the story, and I think it did a lot of good in the matter of public and employee relations to give the production man the waste treatment man's side of the picture.

John W. Wakefield, Sanitary Engineer, Florida State Board of Health, Jacksonville, Fla.:—I fully agree concerning the education of the manufacturing personnel, and I think I have an example that will bring that out. We had a citrus plant in Florida that at one time had a waste treatment system consisting of approximately 48 hr. of aeration. Waste containing about 8,000 p.p.m. of B.O.D. went into the aeration system principally as sugar; it came out as yeast, so they didn't reduce the B.O.D., but they did make better food for the fish. By being careful with the molasses evaporators and educating the personnel to turn the hoses off when they got through cleaning up, the citrus plant eliminated that waste completely.

Incidentally, the plant is also profiting by the recovery of considerable citrus juice that formerly went down the drain. Strong waste that can't be eliminated is diverted to molasses evaporators.

Mr. Heller:—This statement probably has been made many times, but I think it's worth repeating. There is a major distinction to be made in industrial waste control. You must differentiate between the process waste problem and the problems associated with housekeeping and maintenance. All too often these two concepts are somewhat scrambled. It is principally the chemical engineering approach

that permits you to unscramble these two fundamental problems. It is quite fundamental and elemental to go back in the process and to compare the various processes in relation to the waste problem. It doesn't follow that after you have solved the process waste problem, you no longer have an industrial waste problem. You must recognize that along with the solution to the process waste problem, you also have the constant problem of education and maintaining a high level of housekeeping control and maintenance.

MEETINGS OF INTEREST

1956

May 12–15	**German Engineers Association Centenary Celebration.** Verein Deutscher Ingenieure Prinz-Georg-Strasse 77/79, Dusseldorf, Germany.
May 15–17	**Eleventh Purdue Industrial Waste Conference,** Purdue University, Lafayette, Ind. Professor Don E. Bloodgood, School of Civil Engineering, Lafayette, Ind.
May 19	**Third Industrial Hygiene Conference,** University of Texas, Austin, Texas. Associate Professor E. F. Gloyna, Engineering Building, University of Texas, Austin, Texas.
May 23–26	**National Society of Professional Engineers,** Ambassador Hotel, Atlantic City, N. J.
May 28–Jun. 3	**General Association of Hygienists and Municipal Technicians,** 36th Congress, Paris, France.
Jun. 4–8	**American Society of Civil Engineers,** Knoxville, Tenn.
Jun. 18–22	**Gordon Research Conference on Stream Sanitation,** Kimball Union Academy, Meriden, N. H. Dr. W. George Parks, Director, Gordon Research Conferences, University of Rhode Island, Kingston, R. I.
Jun. 18–23 and 25–30	**Bioxidation of Organic Wastes,** Manhattan College, New York, N. Y. Assistant Professor W. Wesley Eckenfelder, Civil Engineering Dept., Manhattan College, New York 71, N. Y. Special course limited to 18 persons at each of two sessions.
Jun. 26–28	**Interstate Sanitation Seminar,** 10th Anniversary, Williamsburg, Va.
Aug. 20–31	**Massachusetts Institute of Technology.** Disposal of Industrial Wastes by Biochemical Processing. Summer Session. M.I.T., Cambridge 39, Mass.
Aug. 22–24	**Hydraulics Division, American Society of Civil Engineers,** University of Wisconsin, Madison, Wis. Professor Arno T. Lenz, College of Engineering, University of Wisconsin, Madison 6, Wis.
Oct. 8–12	**Bavarian Biological Institute,** Munich, Germany. Advance course on biology of sewage and stream sanitation. Dr. H. Liebmann, Bayerische Biologische Versuchsanstalt, Veterinärstrauss 13, Munich, 22, Germany. Applications by Sept. 22.
Oct. 8–11	**Federation of Sewage and Industrial Wastes Associations,** Los Angeles, Calif.
Oct. 15–19	**American Society of Civil Engineers,** Annual Meeting, Pittsburgh, Pa.
Nov. 12–16	**American Public Health Association,** 84th Annual Meeting, Atlantic City, N. J.

Stream Pollution

AQUATIC LIFE WATER QUALITY CRITERIA

Second Progress Report *

AQUATIC LIFE ADVISORY COMMITTEE OF THE OHIO RIVER VALLEY WATER SANITATION COMMISSION

Cincinnati, Ohio

FOREWORD AND ACKNOWLEDGMENT

This is the second formal report of a group of biologists and fisheries scientists who have generously responded to an invitation from the Ohio River Valley Water Sanitation Commission to aid in the formulation of water-quality criteria. The first report of the committee was published in THIS JOURNAL (**27**, 3, 321; Mar., 1955). It dealt with a definition of the meaning of water quality suitable for fish life and then set forth recommendations for dissolved-oxygen requirements, evaluated the effect of hydrogen-ion concentration and outlined criteria for judging toxicity of wastes by bioassay.

In this second report the committee states its findings and conclusions with regard to temperature, dissolved solids, settleable solids, chloride ion, fluoride ion and color. In addition, the committee provides supplementary data and discussion on the validity of the dissolved-oxygen requirements presented in the earlier report.

The committee currently includes the following members:

L. L. Smith, Jr., Department of Entomology and Economic Zoology, University of Minnesota, *Chairman*.

B. G. Anderson, Head, Department of Zoology and Entomology, The Pennsylvania State University.

W. A. Chipman, Chief, Special Shellfishery Investigations, U. S. Fish and Wildlife Service.

James B. Lackey, Department of Civil Engineering, University of Florida.

O. L. Meehean, Assistant to the Director, U. S. Fish and Wildlife Service.

Edward Schneberger, Superintendent, Fish Management Division, Wisconsin Conservation Commission.

W. A. Spoor, Department of Zoology, University of Cincinnati.

C. M. Tarzwell, Chief of Aquatic Biology, Robert A. Taft Sanitary Engineering Center, USPHS.

It should be mentioned that Dr. Meehean, under whose auspices the committee was activated in 1952, is also a commissioner; he represents the U. S. Department of the Interior on the Commission. W. G. Hamlin, sanitary engineer on the Commission staff, serves as secretary to the committee.

In releasing this report for publication, the chairman and members of the Commission acknowledge with appreciation the continued and valued public service being rendered by the committee in promoting the practical application of specialized knowledge to water pollution control.

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The first report of the Aquatic Life Advisory Committee included an outline of objectives and basic criteria on which suitability of water for aquatic life would be based, in addition to discussion of specific requirements. Fundamentally, all recommended criteria are based on conditions neces-

* Submitted to the Ohio River Valley Water Sanitation Commission, January 11, 1956.

sary to maintain a well-rounded fish population and a sustained production of a harvestable crop. Where water uses other than for fish production take priority over this use, other criteria will of necessity take precedence. In waters where production of desirable fish crops is the primary consideration, the criteria set by this committee are considered to be minimum requirements. In many cases absolute limits cannot be set on concentrations of pollutants but bioassay, as defined by the committee, must be the final basis for judgment of water suitability. With these principles as a guide, the committee in this second report presents discussions and recommendations covering additional materials and physical conditions affecting the aquatic habitat.

Temperature Requirements

Aquatic organisms in the temperate zone are adapted to seasonal fluctuations in temperature between 0° and about 32° C. (32° to about 90° F.). Most of these organisms become dormant, and a few may die, when the temperature falls to the freezing point of the water, and only a relatively few seem able to survive, let alone complete a normal life cycle, at 35° C. (95° F.). Not all species can survive over this entire range of temperature. Each species has a characteristic range of thermal tolerance beyond which, especially in the direction of higher temperatures, it cannot survive. For example, the trout, a so-called "cold-water" fish, cannot tolerate high temperatures as well as "warm-water" fishes like bass, sunfish and catfish.

Any change in the temperature of the aquatic habitat will affect the animals and plants living in it, even though the change remains within their ranges of thermal tolerance. Because there is a relationship between temperature and the solubility, dissociation and stability of the substances dissolved or suspended in water, a change in temperature will have an indirect effect upon aquatic organisms, entirely apart from any direct effect, through alteration of the physical and chemical characteristics of their environment. Since body temperature of a fish or lower aquatic organism is very close to that of the water, a change in temperature will have direct effect by action upon the metabolic rate, growth, reproduction and other vital processes. It should be pointed out further that, as a consequence of the temperature effect upon one species, a change in temperature might alter the biotic environment of another species, thereby affecting the latter indirectly through an increase or decrease in food or shelter. The complexity of the problem is increased by the fact that the nature and magnitude of the effects upon aquatic organisms are related, not only to the temperature itself, but also to the rate at which it is changed and to the duration of the altered level.

In view of the number of variables to be taken into account, the biological implications of a change in the temperature of a river are extensive, and probably beyond our ability to grasp in their entirety at present. It is also likely that the direct effect will be of more immediate concern and of greater importance. Sufficient data are available so that a statement can be made with some confidence concerning the conditions under which the temperature of the Ohio River Valley waters may be altered without killing fish. For these reasons the discussion will be limited to the direct effects of temperature upon fish within the range of thermal tolerance described above. Since it seems unlikely (although not impossible) that any problem will entail a lowering of the river temperature, the discussion will be further confined to consideration of the effects of increases in temperature.

In Table I are shown the median heat-tolerance limits of the North American fresh-water fishes for which data are available. In general, not more than one-half the test specimens of each species listed were able to live for more than 24 hr. at the limit given for that species. Inasmuch as the temperature to which a fish has become acclimatized will affect its heat-tolerance limit, the limits shown in the table are for fishes taken from water at summer temperatures (usually between 20° and 26° C. (68° and 79° F.), and probably represent the highest temperatures that can be tolerated by members of the species. Where data are available, the upper

TABLE I.—Median Heat-Tolerance Limits of some North American Fresh-Water Fishes

Scientific Name	Common Name	Median Tolerance Limit		Reference
		° C.	° F.	
Carassius auratus	Goldfish	38.6[1]	101.5[1]	(18)
Gambusia affinis	Mosquito fish	37.3[1]	99.1[1]	(19)
Dorosoma cepedianum	Gizzard shad	36.5[1]	97.7[1]	(19)
Micropterus salmoides	Largemouth bass	36.4[1]	97.5[1]	(19)
		28.9[2]	84.0[2]	(4)
Cyprinus carpio	Carp	35.7[2]	96.3[2]	(4)
Ameiurus nebulosus	Brown bullhead	35.1[2]	95.2[2]	(5)
		34.5[1]	94.1[1]	(19)
Ameiurus melas melas	Northern black bullhead	35.0[2]	95.0[2]	(4)
Notomigonus crysoleucas	Golden shiner	34.7[1]	94.5[1]	(19)
		33.2[2]	91.8[2]	(5)
Lepomis gibbosus	Pumpkinseed	34.5[2]	94.1[2]	(5)
		30.2[2]	86.4[2]	(4)
Hyborhynchus notatus	Bluntnose minnow	34.0[1]	93.2[1]	(19)
		33.3[1]	91.9[1]	(18)
Lepomis macrochirus	Bluegill	33.8[1]	92.8[1]	(19)
Pimephales promelas	Fathead minnow	33.8[2]	92.8[2]	(5)
		33.2[1]	91.8[1]	(18)
Ictalurus lacustris	Northern channel catfish	33.5[1]	92.3[1]	(19)
Chrosomus eos	Northern redbelly dace	33.1[2]	91.6[2]	(5)
Notropis cornutus	Common shiner	33.0[1]	91.4[1]	(19)
		32.0[2]	89.6[2]	(5)
		31.0[1]	87.8[1]	(18)
Semotilus atromaculatus	Creek chub	32.6[2]	90.7[2]	(5)
		31.5[1]	88.7[1]	(19)
		30.3[1]	86.5[1]	(18)
Pfrille neogaea	Finescale dace	32.3[2]	90.1[2]	(5)
Perca flavescens	Yellow perch	32.3[1]	90.1[1]	(19)
		30.9[2]	87.6[2]	(5)
		29.7[1]	85.5[1]	(18)
		29.2[2]	84.6[2]	(4)
Catostomus commersonni	Common white sucker	31.2[2]	88.2[2]	(5)
		29.3[1]	84.7[1]	(18)
Margariscus margarita	Pearl dace	31.1[2]	88.0[2]	(5)
Notropis atherinoides	Lake emerald shiner	30.7[1]	87.3[1]	(18)(19)
Eucalia inconstans	Brook stickleback	30.6[2]	87.1[2]	(5)
Rhinichthys atratulus	Blacknose dace	29.5[1]	85.1[1]	(19)
		29.3[1]	84.7[1]	(18)
Ptychocheilus oregonensis	Squawfish	29.3[2]	84.7[2]	(4)
Salvelinus fontinalis	Common brook trout	26.1[2]	79.0[2]	(5)
		25.3[1]	77.5[1]	(18)

[1] Values based on differing survival times.
[2] Values based on survival for 24 hr.
[3] Values based on survival for 12 hr.

limit of tolerance for southern fishes is essentially the same as that for northern representatives of the species. Consequently, these values should be applicable to the entire Ohio River Basin.

These median heat-tolerance limits are too high to be recommended as the limit for the Ohio drainage basin, inasmuch as the limit should be set at a temperature which will permit all fish to live. On the basis of available information, a temperature of 2.5° C. (4.5° F.) lower than that given for each species should permit most, if not all, members of that species to survive indefinitely. It must be emphasized, however, that the data apply merely to the ability to survive. Many fish are unable to complete their life cycles unless the temperatures at the time of spawning and hatching are as much as 15° C. (27° F.) below median tolerance limits.

The fact that the brook trout is the least tolerant of the fishes listed in the table is consistent with the designation of the salmonids as "cold-water" fishes. The inability of this group to tolerate warm water suggests that industries likely to cause an increase in stream temperature should not be located on trout streams.

With regard to the rate at which the temperature is changed, the North American fresh-water animals studied so far can tolerate, or become acclimatized to, increasing or decreasing temperatures over a wide range if the change is gradual, but it is generally believed that an abrupt change greater than about 5° C. (9° F.) may affect them adversely.

The duration of an increased temperature must not be disregarded since its effect on the aquatic life in a stream is likely to be profound. A relatively minor aspect of this phase of the problem is the fact that a fish can withstand a temperature in the vicinity of its 12- or 24-hr. median heat-tolerance limit for some hours before it is likely to succumb because exposure time affects the lethality of a particular high temperature. As a consequence, it is possible for a fish to survive after a short period of exposure to a temperature that would be lethal in 12 or 24 hr. if it is returned to cooler water. The practical application of this fact is doubtful, however, partly because it would be difficult to control the number of hours during which the stream could be heated above the tolerable temperature and partly because the effects of high temperature are not immediately evident.

Of greater importance is the effect of the increased temperature on the composition of the stream population. If the stream were to be held at 5° C. (9° F.) above the normal (natural) temperature to which the existing organisms had become adapted, the reproductive cycles, growth, and other phases of the life history might be affected in such a way that the entire population would be altered. Organisms which require that the eggs be chilled, for example, might be unable to maintain themselves. Thus the entire ecological picture could be changed; whether for better or for worse it is impossible to predict at present. Further, if heat-producing industries were to be so regulated that there would be but little seasonal variation in temperature (e.g., if it were permitted that more heat be added to a river during the winter months than during the summer), unpredictable changes might occur.

It is also necessary to consider the nature of the system by which heated water is to be introduced into the rivers. It seems feasible to base temperature criteria on the condition of the river after mixing with the effluent, but this involves the problem of mixing. Because fish are able to detect small differences in temperature, and will move in temperature gradients to preferred temperatures within their range of thermal tolerance, it is probable that they would avoid an effluent

heated to intolerable levels. It is necessary, however, that they have an opportunity to avoid this effluent and, further, that the zone of heated water not extend out into the river so far that it forms a barrier to upstream movements of the fish.

In view of these considerations, the Aquatic Life Advisory Committee recommends that, in order to maintain stream conditions capable of producing an annual harvestable fish crop comparable to that produced in natural waters of the particular area under consideration, waste discharges be so controlled that the temperature of the receiving water:

1. Shall not be raised above 34° C. (93° F.) at any place or at any time.
2. Shall not be raised above 23° C. (73° F.) at any place or at any time during the months of December through April.
3. Shall not be raised in streams suitable for trout propagation.

Dissolved Solids Requirements

Water which is devoid of dissolved materials does not occur naturally and, even if available, would not be desirable because it will not support aquatic life. Dissolved gases and solids are present in all natural waters and their presence in favorable concentrations is essential for the growth, reproduction and well-being of aquatic organisms. For peak productivity these materials must be present in optimum concentrations. When the concentrations drop below or rise above the optimum, productivity decreases. Below the optimum the concentration serves as a limiting factor; above the optimum the concentration of a substance may inhibit the activities of the organisms in many different ways. If concentration is greater than the optimum, organisms are killed. The presence of certain substances synergizes the effects of other materials and antagonizes those of still others. When the dissolved substances are in physiologically balanced concentrations, extremely high concentrations of many substances can be tolerated without harmful effects.

Different organisms vary in their ability to tolerate, let alone maintain, normal activity in high concentrations of dissolved substances. Some fishes are equally at home in sea water and in fresh water, but others are reported to die in water where the total dissolved materials are present in no higher concentrations than in fish blood. The widely prevalent notion that the limit of salinity tolerance of fresh-water fishes is, in general, the equivalent of 7,000 p.p.m. sodium chloride is misleading. While some substances can often be tolerated in relatively high concentrations, others are toxic in concentrations of less than 1 p.p.m. or, in some instances, of a few parts per billion.

Measures of total dissolved solids, whether in terms of parts per million, conductivity, or osmotic pressure equivalents, are inadequate as an index of toxicity. In general, the conductivity and osmotic pressure of a solution vary with the actual concentration of the dissolved solids. Many organic compounds, however, contribute to the osmotic pressure of a solution but not to its conductivity.

Since the capacity of a water course to reduce the toxicity of a waste changes as the quality of the water changes, the nature of the particular receiving water is another factor which must be taken into consideration. The problem is heightened because water characteristics may be highly variable from stream to stream and from season to season.

When the many factors that enter into the problem of the disposal of dissolved solids are considered, it is evident that no simple answer is available. It is recommended, therefore, that bioassay be used to determine the degree of dilution essential for the safe disposal of brines and other complex wastes which are high in dis-

solved solids. Local species of fishes and dilution water from the receiving water course should be used in the assays.

Settleable Solids Requirements

Settleable solids may be organic or inorganic materials or various mixtures of them. Taken as a group they can affect a stream in several ways. The addition of organic wastes can result in the production of sludge deposits which change the character of the bottom fauna and eliminate the fish food organisms, reduce dissolved oxygen, and produce noxious substances.

The addition of inorganic material such as sand, silt and mud, affects the productivity of a stream directly in two ways. The finer materials produce turbidity which limits the penetration of sunlight and therefore the growth of plants, especially algae, which is an important link in the food chain of a stream. The heavier materials settle out and may partially or completely cover and destroy rich food-producing areas and spawning grounds.

If inorganic materials such as washings from gravel pits, wastes from hydraulic and placer mining operations and other activities, or the products of soil erosion are added to a stream in large quantities they may fill pools, destroy rich food-producing areas, or completely choke the stream. In some instances the stream bed has been filled with such deposits to the extent that the water flows in a thin sheet over shifting bottoms which are largely devoid of aquatic life. In other cases, however, these materials may be added to streams in quantities which are not noticeable on general inspection but which are sufficient to reduce drastically the production of bottom organisms important as fish food.

In studies carried out in connection with stream improvement activities, it was found that different types of stream bottoms vary greatly in their productive capacity for fish food organisms (31). On the basis of bottom studies made in Michigan during the period 1930–35, and subsequently confirmed in principle by other workers, it was found that, when sand was given a population rating of 1, the relative productivity of the other bottom types was as follows: marl, 6; fine gravel, 9; sand and silt, 10.5; gravel and sand, 12; sand, silt, and debris, 12; gravel and rubble, 53; sand and gravel with aquatic plants, 67; aquatic mosses on fine gravel, 89; moss on coarse gravel, 111; moss on gravel and rubble, 140. The richest areas were the plant beds; *Vallisneria* sp. had a rating of 159; *Ranunculus* sp., 194; watercress, 301; and *Anacharis* sp. (= Elodea), 452. It is apparent, therefore, that the destruction of plant beds and the covering of gravel or rubble areas with silt, sand and mud will greatly reduce the production of fish food organisms.

It was also found that bottom areas did not have to be completely covered in order for the productivity to be greatly reduced. Only a small amount of sand or silt shifting in and around the gravel of the bottom eliminates much of the area suitable for the attachment or hiding of the aquatic insects and drastically reduces the total production of these forms. Small amounts of sand, not discernible by casual inspection but evident only on close examination of the bottom materials, can bring about significant changes.

To the best of our knowledge adequate data are not available on the amounts of inorganic materials which can be added to a stream without significant harm to its productive capacity. The direct effect of turbidity and suspended solids on fishes is not a satisfactory criterion, since it has been found that fish can withstand large concentrations of suspensoids without any apparent harm. The real influence on fish populations is exerted indirectly through a reduction

of the food supply. In the Missouri River, for example, fish withstand turbidities of 5,000 p.p.m. or more with no apparent direct harmful results but the productivity of the bottom areas is very low and the fish populations in consequence are small. Studies carried out in Oklahoma by Wallen (33) showed that fish were not directly affected by turbidities of several thousand parts per million. Criteria for judging the amount of inorganic materials which may be added to a stream, therefore, should be based primarily on the effect on the productivity of the stream bottom rather than on the acute or direct effect on the fishes. The deposition of materials on the bed of streams may also be detrimental to fish reproduction because it covers spawning areas, smothers eggs, or makes areas unsuitable for spawning activities.

Since there is a lack of exact information concerning the effects of settleable solids on fish-food production, fish spawning, and phytoplankton production, no criteria on the amount of such material which may be added safely to a stream can be formulated at this time. It is recommended, however, that organic wastes not be added to a stream in such quantity that they alone or in combination with inorganic materials form sludge beds or change the physical nature of the bottom.

Chloride Ion Requirements

The chloride ion, as a component of an aquatic habitat, can be considered in three areas of significance: (a) it is a nutritional requirement; (b) it might be toxic; and (c) it exerts an osmotic effect. The problem is to decide whether it is important enough in any of these areas to require limitations on the total content in river water.

The nutritional aspect may be disregarded since water quality changes will reflect the addition, rather than the removal, of chloride ion.

There is no convincing evidence that chloride ions have any specific toxicity. The toxicity of physiologically unbalanced solutions of various chlorides (salts), including sodium chloride, is apparently attributable to the specific toxicity of the cations present and not to any toxicity of the chloride ions (anions). The specific toxicity of the different cations varies greatly. Sodium, calcium, strontium, and magnesium are among the least toxic, while the chlorides of such metals as copper, mercury, cadmium, zinc, and lead are among the most toxic. Because the toxicity of the chloride ion has been found to be so much less significant than that of the cations associated with it, an expression of chloride ion concentration in any water has no meaning as far as toxicity is concerned.

Physiologically balanced mixed salt solutions, such as seawater, may be harmful to fresh-water organisms because of their excessive over-all salt content and osmotic pressure rather than the specific toxicity of any particular ions present. Provided that the salts and other substances dissolved in water are balanced against each other so that any individual toxic effects are excluded, certain hardy fresh-water fishes can tolerate waters of osmotic pressures equal to those of their own bloods or even higher for extended periods. Other fresh-water fishes, however, have been reported to be unable to tolerate balanced salt solutions with concentrations of 2,000 to 4,000 p.p.m. It is not known whether a typical fresh-water fish can complete a normal life history in water of relatively high osmotic pressure, nor is it known how osmotic pressure affects the life processes of other fresh-water organisms. It is, therefore, impossible at present to define the maximal safe osmotic pressure of a fresh-water environment. Presumably, the tolerable osmotic pressure entails a salt concentration far higher than the limits imposed by industrial and

municipal requirements. If the concern is only with different concentrations of a particular salt mixture such as sea salt, the composition of which is known and uniform, the chloride content of the solutions (which is easily determined) can be a useful index of osmotic strength. However, when consideration is given to mixed salt solutions of unknown and varying composition such as oil well brines and other industrial wastes, their chloride ion content is not a reliable index of osmotic strength. For example, an industrial-waste brine containing a large amount of sodium sulfate can be much more active osmotically than another brine with a much higher chloride ion content which contains only sodium and calcium chlorides. It is therefore impossible to generalize on the relationship between chloride ion concentration and osmotic, toxic, or over-all pollutional strength in industrial waters.

Each particular mixture of chlorides and other salts found in polluted waters should be considered individually, with attention being given to the specific toxicity of all the components, their synergistic and antagonistic relationships or interactions, and the osmotic pressure of the solutions under consideration.

The Aquatic Life Advisory Committee is of the opinion that an expression of chloride ion concentration has, in itself, no practical significance as far as aquatic life is concerned since the cations are the potentially toxic agents. It is therefore recommended that bioassays be used for the evaluation of the effects on aquatic life of brines and other industrial wastes containing chlorides.

Fluoride Requirements

Fluoride is present in varying amounts in the earth's crust. In some areas it is fairly abundant in water supplies while in other areas it is almost absent, the range being in general 0.0 to 2.0 p.p.m. The majority of natural waters even in areas of high fluoride content contain less than 4.0 to 5.0 p.p.m. In the Ohio River Basin, analysis of various waters and water supplies indicates a range of 0.001 to 4.0 p.p.m. in ground waters and about the same range in surface waters.

In certain parts of the country industrial plants have released large quantities of fluoride into the atmosphere. This material has settled on the vegetation in considerable amounts and has caused harmful effects to domestic stock. Fluorides released in such a manner may eventually become stream pollutants. New industrial processes now under development and expansion are adding increasingly large amounts of fluorides to streams as liquid wastes which may become pollution problems. Published information on the effects of fluorides on fishes indicates that very little information is available.

The USPHS has recently carried on bioassay studies directed toward the determination of toxicity fluorides to fishes. Tests were made with sodium, potassium and calcium fluorides in hard and soft waters. Since calcium fluoride is quite insoluble, the higher concentrations of this salt formed a precipitate and it is not definitely known how much fluoride ion was actually present in the test solutions. The solubility of CaF_2 is reported to be about 16 to 17 p.p.m. Each of the fluorides was found to be more toxic in soft water. It is probable that the calcium in the hard water caused some of the fluoride ion from the sodium and potassium salt solutions to precipitate and thus reduce their toxicity. Potassium fluoride was found to be most toxic. On the basis of the amount added to the solution the 10-day TL_m of potassium fluoride was 64.5 p.p.m. in soft water and 150 p.p.m. in hard water. Since probably not more than 16 to 17 p.p.m. of the fluoride were in solution at any one time and, since some chronic effect was evident, it may be concluded that in the disposal of in-

dustrial wastes, the fluoride content should be kept at less than 15 p.p.m. This amount is 10 times the concentration (1.5 p.p.m.) considered safe for human use. Therefore, in those areas where surface waters are sources of domestic supply, the enforcement of the drinking water standards will protect the fish population from harmful concentration of fluorides.

In view of these facts and the absence of data concerning the chronic effects of fluorides on aquatic organisms and, further, with the knowledge that fluoride effects are cumulative in domestic animals, the Aquatic Life Advisory Committee recommends that fluoride-ion concentration in any stream not be permitted at levels above those found safe for human consumption.

Color Requirements

Aquatic plants play an important role in the productivity of a stream. In the first place, they serve as food for aquatic animals, primarily the invertebrates which in turn become food for fishes. The larger plants supply shelter, protection and support as well as food. Good fish-management programs call for a balanced aquatic vegetation.

Plant productivity depends on many factors. In general the requirements for aquatic plants are much the same as for all other green plants. Among these is a good supply of the inorganic nutrients such as available nitrogen, phosphorus, potassium and various other elements together with carbon dioxide and light. The restriction of any one or more factors limits the productivity of the plants.

Water absorbs light differentially. It has been shown that a layer of distilled water 1 m. in thickness absorbs 53 per cent of the total solar radiation. It absorbs 30 per cent of the red-orange band (6,500Å.) but less than 5 per cent of the blue (4,500Å.), the portions of the spectrum which are absorbed to the greatest extent by chlorophyll and by green leaves. The band at 7,500Å. is over 90 per cent absorbed. While about 53 per cent of the total solar radiation is absorbed in 1 m. of distilled water, natural waters absorb far more light. In one of the most transparent lakes investigated, 60 per cent of the incident light was absorbed and in many cases as much as 95 per cent is removed in the first meter.

The light intensity at which photosynthesis is balanced by respiration in some submerged vascular plants has been found to be 2 per cent of full sunlight on clear summer days. For some algae the compensation point is considerably less. While many plants can maintain themselves at 2 per cent of full sunlight or less the intensity must be much greater for maximum production. It is estimated that 25 to 50 per cent of full sunlight is necessary for many green plants to reach maximum photosynthesis.

In order to maintain the most favorable conditions for the growth of higher aquatic plants it is essential that the transparency of the water be such that at least 25 per cent of the total solar radiation reaches the plants. While this condition is not attained in many of the larger streams even when they are unpolluted, it is desirable to restrict the addition of any substances to natural waters that reduce the productivity of the aquatic vegetation through lessening of light penetration.

Evaluation of Literature on Dissolved Oxygen Requirements

Faced with the task of recommending a dissolved oxygen criterion suitable for the maintenance of a well-rounded fish population in the Ohio River Valley waters, the Aquatic Life Advisory Committee found it necessary to analyze the literature rather carefully in order to obtain acceptable data. The proposed value of 5 p.p.m. for at least 16 hr. within any 24-hr. period (First Progress Report) is based on a study of all relevant papers known to the ALAC, and in the opinion of this Committee represents the

best estimate of the correct value that can be made in the light of the information available at present. Some of the questions that have arisen in connection with the study by ALAC of the dissolved oxygen problem have suggested to the Committee that a description of its approach to the literature might be of use to others interested in this matter.

Although numerous investigators have dealt with the oxygen requirements of fish, the literature is so varied as to the species studied, the conditions under which they were studied, and the types of information sought that by no means all of the published work has direct bearing on the particular problem. It is necessary to bear in mind constantly that the Committee is seeking to define the level of dissolved oxygen at which a fish population can maintain itself for many years. This entails consideration of the effects of age, temperature, activity and other factors upon oxygen requirements; it is not enough to know merely the minimal level of oxygen at which a few specimens can resist death by asphyxiation for a few days or weeks. All data must be analyzed in terms of their applicability to the conditions actually encountered by fish in a natural environment. Generally speaking, each paper was analyzed with the following questions in mind:

1. Do the conditions under which the data were gathered reflect those encountered by fish in nature, or can they be related to natural conditions in the Ohio River Valley?
2. Are the species under consideration such that the data can be applied to a well-rounded fish population in the Ohio River Valley?
3. Do the data show anything more than that the fish can resist death by asphyxiation for a time under conditions of low oxygen concentration?

With regard to the first question, the oxygen requirements of a fish living in clean water vary widely with the temperature and with muscular activity. The temperature effect is well known, and it should be sufficient to point out that a fish uses several times as much oxygen at 25° C. as at 10° C. (8)(10)(13)(14)(15), and that the asphyxial concentration is greater the higher the temperature (14)(22). The fact that Ohio River Valley streams may reach 30° C. in the summer, as shown by Brinley (7), makes this point a critical one. The effect of activity on oxygen consumption, too, is clear cut, from two to more than four times as much oxygen being required by a fish when it is active as when it is quiescent (13)(15)(30). It is important that it be realized that activity plays a prominent role in the life of a fish under natural conditions. Not only must the fish be active in foraging for food and avoiding capture by predators, but also it must remain active to some extent to maintain its position against the current if it lives in flowing water. It is necessary to take into account also the fact that among fish as among other animals the metabolic rates (and consequently the oxygen demands) of the younger stages have been found to be greater than those of adults (23)(24)(26)(28). This fact is all the more important because most of the data in the literature pertain to the requirements of adult fish. If the water is polluted, the amount of dissolved oxygen required to maintain a fish is likely to become greater (9)(32)(35)(36). Polluting agents that the fish might be able to endure in the presence of an adequate oxygen supply can become lethal when the dissolved oxygen concentration is barely adequate to sustain life in the absence of such agents.

With regard to the second question, the applicability of the data to a well-rounded population, the Aquatic Life Advisory Committee has kept in mind the fact that species vary in their abilities to cope with low levels of dissolved oxygen. Generally speaking,

the so-called coarse fishes seem to be hardier, with respect to their tolerance of low levels of dissolved oxygen, than the pan and game fishes. For this reason it has been necessary to take into account the types of fish employed in the papers under consideration.

In connection with the third question, it is important that it be recognized that fish have several means by which they can adjust themselves to a reduced oxygen supply if it does not fall too low, or which will enable them to tide themselves over periods during which the oxygen concentration reaches asphyxial levels. Certain devices (e.g., an increase in the rate at which water is pumped over the gills) enable a fish to adjust to low, but not necessarily asphyxial, oxygen concentrations (3)(11)(25). By means of such devices a fish may live for extended periods without apparent harm, although the research that has been done in this area is too meager to permit the conclusion that all members of a well-rounded population can live for long periods, let alone thrive, under such conditions. There is some evidence, in fact, that although fish may show no external signs of deterioration at low, but not asphyxial, oxygen concentrations, their physiological processes may be altered. Among brook trout, at any rate, the oxygen content of the water must be in the vicinity of 75 per cent air saturation (about 7.6 p.p.m.) at 15° C. in order to supply enough oxygen for them to maintain full activity. Seventy-five per cent air saturation is inadequate at 20° C., and full saturation is required at 25° C. (12)(15). It has been reported, too, that the hardy bullhead is unable to become acclimatized in an increased temperature when maintained in water low in dissolved oxygen, although such acclimatization is a normal property in the presence of adequate oxygen (6).

For these reasons, and until there is proof to the contrary, the Committee cannot accept oxygen levels that require the use of such devices as adequate to maintain a well-rounded population. Other means, such as a decrease in activity when the fish become quiescent, even to the extent that they do not feed (2)(12)(16)(20)(25), the accumulation of unoxidized acid, presumably lactic acid—the so-called "oxygen debt" (3)(17)(21), and gulping at the surface (1), are emergency measures that enable the fish to resist asphyxiation for a while, but not indefinitely. Their survival depends on their being given opportunity within a reasonable time to recover in water of adequate oxygen content. There are some indications that, by a process of acclimatization, fish may become able to survive at oxygen concentrations that would ordinarily prove to be asphyxial (12)(16)(29). This apparent acclimatization, however, requires that the fish remain almost completely quiescent, and it is believed that it will prove to have no major effect on the oxygen requirements associated with activity (12). Activity being an important aspect of existence under natural conditions, acclimatization to low oxygen concentrations does not seem to the Committee to hold much promise as a solution of the problem of maintaining a well-rounded population of fishes.

The papers in the literature dealing with the oxygen requirements of fish are of two general types: (a) experimental studies, in which fish are observed either under laboratory conditions, usually with as many as possible of the known variables controlled, or under field conditions, in which fish are placed into natural environments known to have the characteristics (e.g. dissolved oxygen concentration) under consideration, and (b) field studies, in which the variable in question (e.g., dissolved oxygen) is measured in the natural habitat and relation to the quality of the fish population found in that habitat. Both experimental and field studies contribute information useful for the purposes of the Aquatic Life Advisory Committee, but

as they have been conducted so far each type has characteristics that must be weighed before the results can be applied to the Committee problem.

The value of the experimental approach lies in the fact that as a rule the fish are studied under controlled conditions, so that the relationship between temperature, activity, or other variables and the oxygen requirement can be tested with some assurance. The fact that the animals are usually maintained under conditions favorable for survival at low oxygen concentrations makes it necessary that the differences between experimental and natural conditions be borne well in mind as oxygen concentration data are evaluated. Thus, the use of a clean water supply, while usually desirable in experimental work, is likely to enable a fish to survive for a longer period at low oxygen concentrations than it would be able to do in a polluted body of water. Feeding prepared foods, and placing the fish into a clean glass vessel either by itself or with a few others of the same species and size removes the fish from the food-seeking, predator-avoiding, current-resisting demands of its natural environment. Withholding food, another very common experimental practice, lessens the oxygen requirement. The importance of taking the temperature into account is obvious.

A paper based on field studies has the advantage of indicating the oxygen concentration at which a population of fish will maintain itself. Furthermore, it proves the suitability of that oxygen concentration for other organisms, including those comprising the basic food supply of the fish, that inhabit the same environment. The fish would not remain in an area in which they could find nothing to eat. While not open to the criticism that the fish are not subject to normal environmental conditions, field studies may nevertheless be weakened by the fact that the number of uncontrolled variables encountered in a field situation makes it difficult to be certain in all cases that it is the oxygen concentration alone that accounts for the findings. This is not an insurmountable difficulty, by any means, but it must be borne in mind in the analysis of a paper.

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THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

EASING THE LOAD

BY ROBERT E. SIMON

Superintendent, Sewage Treatment Plant, Orlando, Fla.

There are many little things that can be done around the sewage treatment plant and lift stations that will help make operating easier and increase the chances of the superintendent getting a full night's untroubled sleep. At the Orlando, Florida sewage treatment plant a number of innovations were developed to ease the load on the operating personnel.

Lift Station Failure Alarm

One of the best additions to the overall maintenance setup is an electric failure alarm serving four of the largest lift stations. Even though automatic stand-by pump units have been provided in these stations, and are tested each day to make sure they are operating properly, there is always a chance that after the gasoline engines have stopped and started a number of times they may become vapor bound or flooded. It happens more frequently with the larger engines.

Telephone lines have been connected between each of the four main lift stations and the sewage treatment plant. To these lines a normally open relay is installed in the electric control circuit for the gasoline engine at the lift station. At the treatment plant a few low resistance D.C. relays have been installed to operate 110-v. A.C. relays in the alarm system. To distinguish which station is in need of attention, a different colored light was installed for each lift station. However, only one claxon was installed for the control board. A silencing button and an automatic reset are provided for controlling the horn. The only unsatisfactory feature in this arrangement is that if a power failure occurs at one lift station and the claxon is turned off, it is necessary to watch the lights on the control board to detect a power failure at another lift station. The claxon will not reset automatically until all the lift stations are cleared.

Daily testing of the alarm system by the lift station maintenance personnel is standard operating procedure. A predetermined signal is used so the treatment plant operator can distinguish between testing and a power failure. This system was designed, built and installed by plant personnel and it has paid for itself many times in facilitating lift station operation.

Radio Equipment

Another nice addition was the installation of two-way radio equipment in all the sewage treatment plant service vehicles. Not only is the location of each truck known but if someone gets in a tight spot help can be obtained within a few minutes instead of an hour or two. It also saves travel time on equipment.

Plant Housekeeping Techniques

Sludge Hopper Wash-Down

Under the hot Florida sun, raw sludge clinging to the walls of the sludge

hopper soon produces odors. To clean the hopper back under a ledge that couldn't be hosed down, a lawn sprinkler of the "Rainbird" type was installed in an inverted position. A full circle of spray washes the corners and the rotating spray arm travels just slowly enough to wash down the walls.

The sprinkler uses fresh water and is turned on manually while the last hopper of sludge is being pumped. It does a beautiful job, not only under the ledge, but on the entire hopper. More automation could be incorporated by use of a solenoid valve in the sprinkler supply line controlled by the sludge pump motor control.

Clarifier Scum Trough Spray

Various methods have been tried to keep the scum trough and scraper arms clean. Usually when the operators pump scum the clarifier scum-scraper arm is on the opposite side of the tank, or they forget to hose it down when there is opportunity. Also trouble was experienced with the wiper blades not wiping clean. The use of a board instead of a heavy neoprene wiper was unsatisfactory. Finally a 3-in. wide nylon brush was fastened on a board, ½-in. thick. This made an excellent wiper blade. A double spray arm (Figure 1) was installed over the scum trough with the sprays directed straight into the trough and also angled in from the back side of the trough. The sprays are actuated by the scum arm raising a long angle iron which operates a hydraulic control valve. The length of the angle iron governs the length of time the spray will stay on. The spray arms were fabricated from ¾-in. galvanized iron pipe with drilled holes. Water supply is from the plant system.

During six months of operation the system has given satisfactory results. It not only keeps the scum arm and trough clean, but also keeps the tank surface relatively free from floating solids.

Effluent Utilization

At present the treatment plant effluent is utilized only in the heat exchanger which cools the water jacket water of a dual-fuel diesel engine generator. Sufficient extra power is available to operate a large-size irrigation pump. Tentative planning for the future includes the use of plant effluent

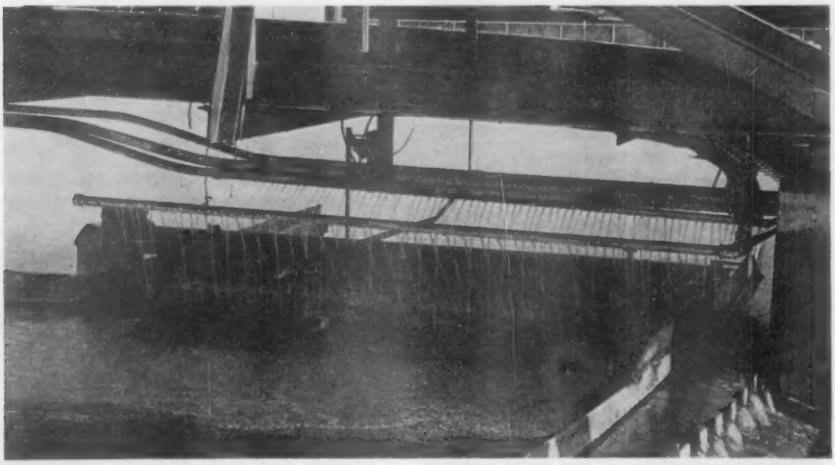

FIGURE 1.—Primary clarifier scum trough spray cleaning apparatus. Note control arm operating hydraulic valve.

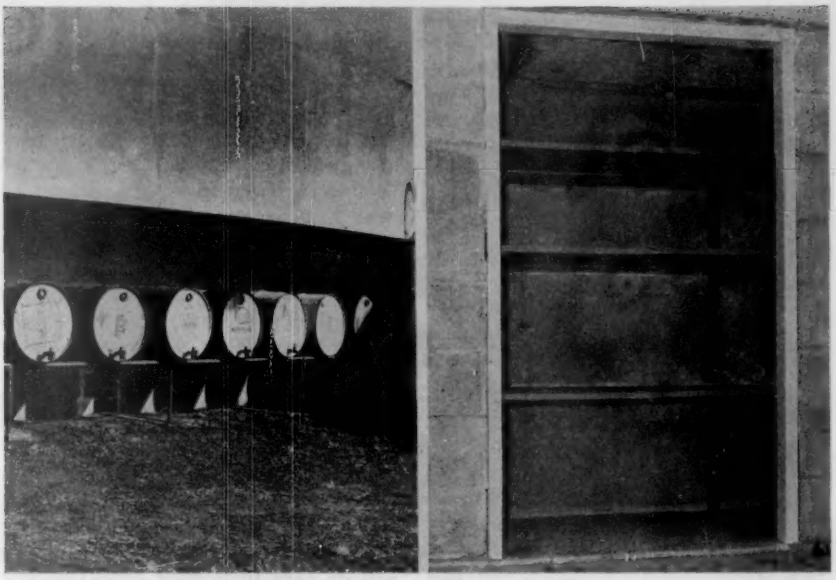

FIGURE 2.—Space under clarifier overhang is utilized for storage.

for irrigation, chlorinator ejector water, equipment wash down and foam control. A fine spray on foam appears to be an effective control measure.

Filter Fly Control

One important, but often overlooked method of odor control is the regular and frequent washing down of scum pits, clarifier walls, flumes, weirs and other structures that come in contact with the sewage. Keeping the spray nozzles on the distributor open is important in order to prevent septicity in any part of the filter. On many distributor arms, a part of the sewage runs back under the nozzle on the outside of the arm and a slime growth may form. If this is not cleaned periodically, filter flies will breed there.

Heavy growths of moss on the trickling filters at the Orlando plant were difficult to control. The plant hydraulics would not permit control of the moss and filter flies by flooding the secondary filters. Putting the filter out of service and drying out the moss was not feasible due to attendant odors.

As a solution, the feeding of chlorine into the filter influent was attempted. The chlorine was fed directly from a one-ton cylinder through a pressure reducing valve and a ¾-in. plastic water hose. A stone diffuser was used on the end of the hose. The chlorine residual at the end of the filter arms was checked and the dosage controlled at just under 10 p.p.m. By the time the ton of chlorine was emptied the filter stone was cleansed of moss. There were no problems due to clogging, nor was the clarifier overloaded. Filter flies and odors were completely eliminated.

Storage Space

Some clarifiers are constructed above grade so that the weirs and overflow channels overhang the clarifier wall. The space under this overhang may be utilized for storage (Figure 2) in mild climates. Under one of these overhangs a concrete floor was poured

and the space blocked in. Shelves were installed, making a good fireproof place for storing paints and lubricating oils. These locations were also used to advantage for a pipe rack and drum storage.

Float Controls

Plastic coated stainless steel fishing line has proven very satisfactory for use on lift station float controls. Stainless steel tapes had to be replaced every three or four months. Since the fishing line has been used there have been no replacements. The line costs less than $0.02 per foot and tests for 60 lb.

Liquid Sludge Loader

Liquid digested sludge has found increased acceptance among nursery men, park department personnel and local farmers. To accommodate this demand, facilities (Figure 3) were recently installed to deliver the sludge directly into tank trucks. The arrangement of the sludge beds and driveway at the Orlando plant makes the illustrated installation both effective and economical. An arrangement similar to this is essential to avoid an otherwise messy and odoriferous condition.

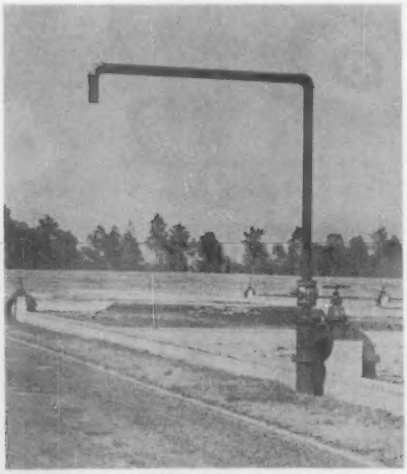

FIGURE 3.—Liquid sludge loader for tank trucks.

Odor Problems

Odor problems occur at the Orlando treatment plant the same as they occur at any plant. Relatively few sewage treatment plants have been without an odor problem at one time or another. Sewage always will have an odor but operating personnel would like to feel that they are doing a much better job today than they were doing some years ago. Nevertheless there apparently are more and more complaints about sewage odor. As one man so aptly put it, you can clean and beautify all you want and use all the psychology possible, and these things may help for a while, but if Mrs. Jones smells sewage long enough she will ultimately complain. Thereafter anything done will do very little good until the odor is gone; even then she will still complain at the slightest provocation. The public didn't complain too much about odors in former days and yet, with modern treatment facilities and improved methods, the plant superintendents are being flooded with complaints. There are a number of possible reasons for all the fuss.

1. The public is being awakened by manufacturers of odor control material to the fact that there is no need to smell sewage odor or any other obnoxious odor. Advertising by manufacturers of odor control materials and statements that sewage treatment plants, if operated properly, will be 100 per cent odor free, have resulted in the construction of residences right up to the treatment plant fence line. Usually the residents do not get any odor for a week, a month, or maybe longer; then a filter is flooded or an unusual amount of supernatant is withdrawn, or the sewer line crew opens a sewer that has been plugged a week or two, and everyone complains.

2. Some consulting engineers have been convincing the municipal officials

and the citizens that modern sewage treatment plants don't smell and practically operate themselves. As a consequence cities build their treatment plants not far enough away from inhabitable areas and developers build too close to existing plants.

3. The increased use of garbage disposal units in the home has had a great deal to do with the increase in the grease and organic load at both the treatment plant and lift stations. The odor of rancid grease is nauseating even to the plant operators. The use of these grinders means the sewage treatment plant will receive not only the domestic sewage but also the garbage. Sewers that formerly operated satisfactorily with ordinary domestic sewage become coated with grease, and the increased solids loading causes the sewage to turn septic before reaching the treatment plant.

4. The growth in population and industry has resulted in increased pollution to the extent that the public is recognizing the fact that something needs to be done.

Odor Control

In an effort to reduce odor complaints, special attention has been directed to conditions at the numerous sewage lift stations. The relatively flat topography of Orlando makes the use of these pumping stations mandatory. Stations range in size from small installations in the residential areas to large facilities in heavily built-up sections. Each station receives a daily checking from the lift station maintenance crew.

The following have helped to ease the maintenance task and reduce odors:

1. Chlorination facilities are utilized at some of the large lift stations to control the septicity of the sewage.

2. All wet well vents in some stations are sealed and ventilation is provided through flagpole vents.

3. Sewer gases are trapped and vented back through the house vents and manholes.

4. An odor counteractant is either dripped or sprayed into the lift station wet well.

Flagpole Vents

The 40-ft. flagpole vents are constructed by the treatment plant staff from a length each of 6-in. and 5-in. diameter steel pipe. The poles are fabricated by welding and set on a ¾-in. base plate which is bolted to a concrete base. A pipe connection is provided from the vent stack to the wet well. Each pole is complete with a lanyard, although flags are not usually flown.

To utilize the vent stacks all openings in the lift station are sealed, except the influent lines and the vent stack line. When the wet well is filling the sewer gases are forced up and out the stack. The 40-ft. height is sufficient to obtain good dispersion of the gases. When the well is pumped down, fresh air is drawn in through the vent. In other words the wet well "breathes" through the flagpole vent stack.

When blowers are used to increase the ventilation they are set to blow into the wet well, thus causing the stack to discharge only. The use of a chemical odor counteractant in the vent stack is very effective.

Wet Well Gas Trap

As the sewage flows into the lift station it draws gases into the wet well from the sewer lines, provided the influent line is not flowing full. If the lines would flow full or if the inlet could be blocked off to prevent the entrance of gases, then the odors at the wet well would be reduced.

To accomplish this closure a tee, with the run in a vertical position, was installed on the influent pipe. In the inlet shear gate slot a low gate

or baffle board was installed so that sewage would back up sufficiently to cover the bottom of the tee. A plug was sealed into the top of the tee in such a manner that it would be easy to remove for cleaning and inspection.

The trap works fine, with a minimum of maintenance. Odors at the station are reduced and the sewer lines are vented through the manholes and house vents instead of coming into the station.

Odor Counteractant

As an additional method of odor control, a liquid odor counteractant * was used in the wet wells of the lift stations. This counteractant has been the most successful material used to date. Apparently it creates a film over the surface of the sewage, counteracting the hydrogen sulfide as it is released from the sewage.

Both spray and drip systems of application are used at the large lift stations while a drip system only is used at the small stations. Sight-feed oilers are used in the drip system so the amount applied can be closely regulated. The feed rate at the large lift stations is 75 lb. per day, a decrease from a maximum of 125 lb. per day.

The odor counteractant is also used at the treatment plant. It is dripped into the influent raw sewage and also fed just prior to discharge on the rotating trickling filters. Dosage rate is approximately 0.5 p.p.m. Odors have been kept under control except for a couple of times, once when some supernatant was drawn to a sludge bed and again when a flooded filter was drained. In the rush to control the odors, too much counteractant was used and the resulting complaints were caused by the predominant counter actant odor.

* "Refreshnaire," a proprietary compound distributed by Refreshnaire Treatment, 3256 E. 11th Ave., Hialeah, Fla.

Odor Complaints

Most complaints about odors from the treatment plant occur in the evening or early morning. The complaints are most prevalent a couple of hours before and after sunset. Usually the workday activities of the neighboring residents taper off about this time and they relax. As a result, they are more aware of any strange odors. Atmospheric conditions at this time of day probably play a part in the prevalence of odors. On days with only a slight breeze and high humidity the complaints may persist on and off all day.

Fortunately, most of the odor complaints are not chronic, and are usually received all at one time. The nearest homes are approximately 300 yards away and many times the neighbors get odors before they are noticed at the plant. Therefore, by close cooperation between the neighbors and the plant personnel, corrective action is quickly taken when odor complaints are received. After the call is received, the person calling is invited to call back if the odors do not subside. Visits are also invited. Usually, the source of the odor can be found and counteracted in a short time. Complaints at the lift stations are now rare.

The combination control using prechlorination to keep the sewage as fresh as possible and treatment with the odor counteractant to combat hydrogen sulfide at both the treatment plant and lift stations has been fairly successful.

It would be a boon to sewage treatment plant personnel if research studies could be undertaken to evaluate the effectiveness of the many odor-control chemicals now available. Actual plant-scale evaluation should be carried out. Most treatment facilities do not have the time, personnel or equipment to properly evaluate the full effectiveness of these products.

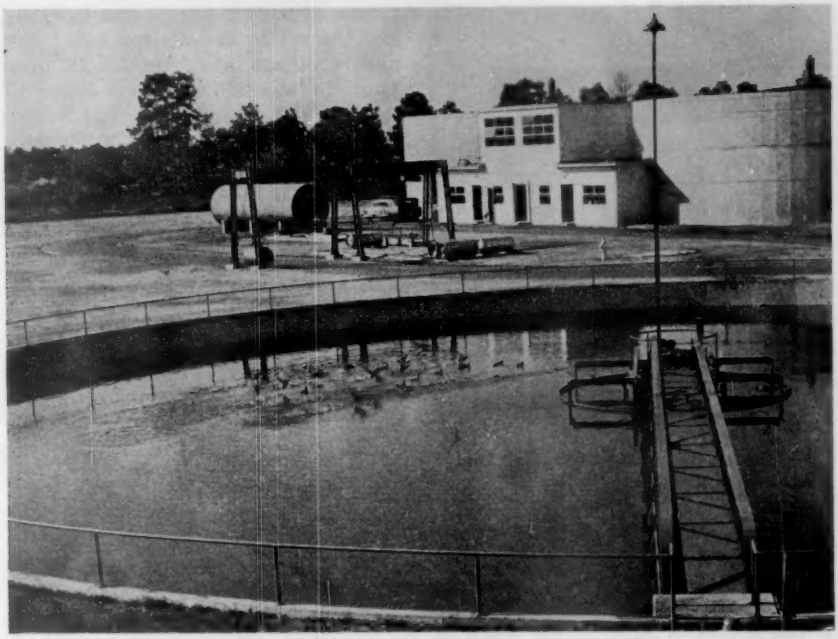

FIGURE 4.—Winter visitors (ducks) feeding on filter fly larvae in the secondary clarifier.

General Appearance

Although flowers, shrubbery, clean windows and polished floors may not help the odor, it is an essential part of good public relations. It is difficult for citizens to complain heatedly about odors if the treatment plant is kept spotless.

Visitors to the Orlando treatment plant during the winter are always impressed by the ducks swimming in the secondary clarifiers (Figure 4). The ducks arrive each winter just after Christmas and stay until March. They fly between a small lake near the plant and the clarifier where they feed on filter fly larvae. Most visitors remember this feature of the plant and indirectly praise the operating personnel for the excellent job of sewage treatment.

ASPHALT-PAVED SLUDGE DRYING BEDS

By Edgar R. Lynd

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In the semi-arid regions of Eastern Washington, where the average yearly rainfall is only 15.07 in., sludge drying on open beds is considered quite practical. For example, from April 1 to October 1, 1955 the Walla Walla area received only 5.87 in. of rain. This sparse precipitation makes for an excellent sludge drying season of about six months.

The removal of sludge from conventional sand drying beds has always

FIGURE 1.—Asphalt-paved sludge drying beds.

presented quite a problem. Power loading equipment cannot be taken onto the beds because of the danger of damaging the underdrains. Also, if the sludge is quite damp, much of it will be mixed in and pressed down into the sand. Eventually, sludge particles will practically seal off the underdrains and drying will be almost completely by evaporation. In seeking a solution to this problem, it appeared that what was needed was a drying surface that could hold up under power equipment and still provide some underdrainage for fastest possible sludge dewatering and drying.

A New Sludge Bed Design

The consulting engineers, who were planning a completely new sewage treatment plant, prepared a new design for the sludge drying beds. A careful study of materials indicated that asphaltic concrete would be the most suitable material to use for surfacing the beds. An area of approximately 20,000 sq. ft. was divided into four rectangular beds of equal size (Figure 1), each measuring 41 ft. by 112 ft. Thorough settling and compacting of the area was done and then a base course of gravel was built up and shaped to the desired size. For underdrainage, one line of 6-in. open joint tile was laid down the center of the bed and extended the full length. A side slope of 4 in. from the outside to center was provided. Asphaltic concrete was then applied in two lifts to a depth of 3 in. A 3-ft. wide strip immediately over the underdrains was left open. This was then built up in the usual manner with course rock and sand. A mold was constructed and dividers of asphalt 9 in. high were then added. Access ramps 10 ft. wide with a 5 to 1 slope were placed in each bed so that access could be made without driving over the center drainage strip.

Costs

The cost of asphalt for the sludge bed area, including dividers and ramps, was about $6,000 or $0.30 per square foot. Total cost of the beds including piping, sand, gravel, and asphalt amounted to approximately $10,000 or $0.50 per square foot.

Sludge Drying Results

As soon as the beds were completed some sludge was immediately drawn to one bed from an old digester that was being cleaned out. This proved to be a mistake, for as the sludge began cracking and drying, it also caused the asphalt to crack. No more sludge was drawn. The Asphalt Institute was contacted and advised that a condition known as "curling" had developed because the sludge had been placed on the asphalt too soon. With the surface perfectly clean, an excellent bond was formed between the sludge and the asphalt. This condition was remedied by spreading some loose material, such as sand, sawdust or dirt on the bed prior to drawing sludge for the first time. After that, no further precautions were required and no more trouble has been experienced.

Sludge Removal

Removal of sludge can be made before it is completely dry if it is to be crushed. However, one drawing was allowed to dry until it could be easily pulverized either with a sludge crusher, or by dragging the bucket of the pay-loader over it. This latter method was employed to break up about 30 yd. of sludge which was placed on lawns around the treatment plant. Approximately 60 days of drying time was required for this method. Ordinarily, sludge can be removed in about 45 days during the drying season previously mentioned. Beds are filled level full or with about 30,000 gal. of liquid sludge for each filling. This gives an average liquid depth of about 9 in. The dry solids content of sludge drawn has averaged 8.7 per cent.

FIGURE 2.—Pay-loader cleaning the sludge drying beds. White strip is center drainage tile with sand covering.

The use of asphalt sludge drying beds has been very satisfactory, and sludge removal is made almost entirely with power equipment (Figure 2). Maintenance requirements have been at a minimum.

DIGESTER SCUM DISPERSION *

By William H. Higgins

Engineer-Manager, Ewing-Lawrence Sewerage Authority, Trenton, N. J.

Beverly, N. J.

The Beverly (N. J.) Sewerage Authority had a serious scum problem just before the old treatment plant was remodeled. The old installation was only a primary treatment plant with two underground rectangular digesters accessible through manholes at each end. The scum problem was quite acute due to an overloaded condition. The only way to break the scum was to hose it down when drawing sludge to the drying beds. The acute problem was remedied when the new treatment plant was placed in operation.

Scum problems in the new plant occurred infrequently. The digestion compartment was underneath the primary settling tanks which were upward flow cone-shaped units. The sludge settled around the outside of the settling tanks. An unusual feature was that an ordinary unheated digester actually operated as a heated tank due to the temperature of the raw sewage. Dye waste from the local dye industry had a pH value between 8 and 11 and a temperature of around 90° F. the year-round. The pH kept the digester on the alkaline side and active and the walls were kept heated so that the oil and scum dispersed, thus preventing extreme accumulations of scum.

Gloucester City, N. J.

Scum problems at the Gloucester City (N. J.) Sewerage Authority treatment plant were not exceptionally troublesome. The treatment plant had primary and secondary digesters with floating covers. There were no scum

* Presented at 1956 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 14–16, 1956.

problems in the secondary digester because it was operated in series with the primary tank. In combating the scum problem in the primary digester, it was only necessary to recirculate the sludge from the bottom of the tank and thus disperse the scum. Normal recirculation of the upper tank for heating kept the scum under control for a long period of time.

Ewing-Lawrence, N. J.

At the Ewing-Lawrence (N. J.) Sewerage Authority treatment plant primary and secondary digesters with floating covers are used. When the treatment plant was placed in operation in October, 1953, there were no connections to the sewer system. By February 1, 1954 there were approximately 1,200 connections; at present connections number more than 5,300. The number of connections is intimately associated with the problem of scum. In January, 1954, General Motors Corp. started diverting their plating wastes from the city of Trenton sewage treatment facilities to the Ewing-Lawrence system. The flow had a ratio of one volume of industrial waste to one of sewage. The limited activity in the digesters started declining rapidly and a scum problem developed. Gas production decreased from 350,000 cu. ft. to 550 cu. ft. per month. During this period the supernatant screen was constantly clogging with a slimy, gelatinous scum. The supernatant liquor had a concentration of suspended solids ranging from 50,000 to 60,000 p.p.m. The scum layer had increased to a depth of 8 ft.

Due to the clogged supernatant screen, the supernatant liquor was transferred to the secondary digester and then through that supernatant screen to the plant influent. The solids settled in the secondary digester and eventually started to digest, and gas production would begin. This occurred several times; when it did the active digester would be used as a primary digester and then the primary digester would become the secondary digester. After a period of operation the scum condition would reoccur and poor digestion would result.

Recirculation

An unsuccessful attempt was made to try continuous recirculation of the entire contents of the digester in an effort to break up an 8-ft. scum layer. Ultimately, both digesters went completely dead. Next a tank truck load of good digested sludge from the Hamilton Township sewage treatment plant was added to the digesters, and some digester action was resumed. Due to a combination of circumstances, including an increased flow diluting the plating waste, the pre-treatment of the plating wastes and the adding of tons of lime to the digesters by means of lime slurry with the raw sludge, the digestion process showed some recovery. Gas production increased to about 350,000 cu. ft. per month. The lime slurry kept the pH up, but the relatively inactive digestion was not sufficient to start the breakdown of the scum blanket.

Again recirculation of tank contents was started but without any success in reducing the scum. Finally, the floating covers were lowered to the rest position, the gas domes and entrance hatches opened and an effort was made to break up the scum with a 1½-in. fire hose at 100 lb. pressure. This attempt also failed because in a few days the scum blanket would solidify. The blanket was so solid it took three men to push a ladder through it for use in hosing down the scum. A one-ton chain hoist had to be rigged to pull the ladder back up through these scum blankets.

In desperation it was concluded that the only way to be rid of the scum would be to clean out the entire contents of the tanks. It was intended to do this by draining the sludge to the drying beds and when the scum layer

was reached it would be broken up with the fire hose and drained to the drying beds.

Use of Alum

A procedure for the orderly shake down of the digesters had just been consummated when information was received concerning some of the experiences and success that had occurred at the Ridgewood (N. J.) sewage treatment plant when aluminum sulfate was used to disperse scum.

In July, 1955, the addition of aluminum sulfate to the raw sludge was started at a rate of 20 lb. per day. Within a week the supernatant selector screens were cleared of scum deposits and returned to service. An occasional back flushing of the screens is all that has been necessary since then. Within 30 days the primary digester scum layer was reduced 2 ft. and the secondary digester scum was reduced 2.5 ft. For the month of August the digesters produced 1,000,000 cu. ft. of gas. This exceptional gas production was due to the scum being digested; production slowly declined as the amount of scum was dispersed. Gas production has stabilized at about 400,000 to 450,000 cu. ft. of gas per month and the scum layer is now only 1.5 ft. thick in the primary digester and 2 ft. thick in the secondary digester.

Another factor affecting digester operation was the heat distribution. When the scum layer was thick it was difficult to maintain an even temperature at 92° F. In fact, in the winter the temperature dropped to 80° F. With the present scum layer a temperature of 95° F. can be maintained at all times, even through the winter.

With this success the use of alum was gradually reduced until now only about 10 lb. per day are fed to the primary digester and about once every two weeks an additional 10 lb. of alum are added to the secondary digester. The scum layer started to build up when the alum addition was reduced to 5 lb. per day. Now the scum layer is soft and permits the gas to bubble through to the gas dome.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The future always holds some good for the man who keeps his faith in it."—Anon.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Annual Report on the Operation and Maintenance of the Rochester, Mich., Sewage Treatment Plant for the Year Ended June 30, 1954 *

By Arthur Maass, *Superintendent*

Operation of the treatment plant was again satisfactory and an effluent of good quality was maintained throughout the year. Settleable solids were reduced 86.4 per cent, suspended solids were reduced from 232 p.p.m. to 79 p.p.m. for a reduction of 65.1 per cent and B.O.D. was reduced 46.0 per cent.

* For last previous extract see This Journal, **26**, 2, 229 (Feb., 1954).

Maintenance problems have been minor. In the fall of 1953, the gas furnace had to be replaced due to serious rusting. Early in the spring of 1954 inspection of the digester floating cover revealed the need for extensive repairs. The wood covering was replaced and all metal surfaces were given two coats of paint. Personnel of the Public Works Department made the repairs.

Metered flow at the plant totaled 201.5 m.g., an increase of 12 m.g. over the preceding year. Of the total flow, Rochester contributed 198.4 m.g. or 98.5 per cent, and the Parke, Davis Biological Farm contributed only 3.05 m.g., approximately one-half the volume of flow recorded in 1952–3. The waste from Parke, Davis is received and metered separately from the Rochester sewage and a complete analysis is made and recorded to provide comparative data for the calculation of service charges.

A total of 11,786 lb. of chlorine was used during the year. This was equivalent to 7.4 p.p.m. applied, and maintained a residual of 0.65 p.p.m. in the effluent. The chlorinator was in service continually except for minor repairs.

The chlorinated plant effluent discharges through an 1,800-ft. outfall sewer into a canal which furnishes water power for a grist-mill in Utica. The canal discharges into the Clinton River below the raw water intake for the Utica municipal water supply. This arrangement effectively eliminates the possibility of polluting the Utica raw water supply with sewage treatment plant effluent. Periodic sampling of the canal and river indicates an ample supply of dissolved oxygen to prevent the creation of nuisances.

Route operation and maintenance were carried out during the year on the plant grounds. No sludge was

TABLE I.—Summary of 1953–4 Operating Data, Rochester (Mich.) Sewage Treatment Plant

Item	Average
Population served	4,300
Sewage treated (m.g.d.):	
Parke, Davis (biological farm)	0.008
Rochester	0.544
Total	0.552
Grit removed (cu. ft. per day)	2.3
Suspended solids (p.p.m.):	
Raw, Rochester	233
Raw, Parke, Davis	42
Effluent	79
Reduction (%)	05.1
B.O.D. (p.p.m.):	
Raw, Rochester	210
Raw, Parke, Davis	52
Primary effluent	116
Chlorinated effluent	111
Reduction (%)	46.0
Chlorine:	
Used (lb. per day)	32
Applied (p.p.m.)	7.4
Residual, 20 min. (p.p.m.)	0.65
Raw sludge:	
Pumped (g.p.d.)	902
Total solids (%)	4.9
Total solids (lb. per day)	375
Volatile solids (%)	73
Volatile solids (lb. per day)	272
Digested sludge:	
Drawn from digester (g.p.d.)	247
Total solids (%)	9.0
Total solids (lb. per day)	187
Volatile solids (%)	49
Volatile solids (lb. per day)	91
pH	7.7
Supernatant:	
Drawn from digester (g.p.d.)	814
Suspended solids (p.p.m.)	6,027
Gas production:	
Volatile solids consumed (lb. per day)	147
Gas produced (cu. ft.) (estimated)	2,088
Operating expenses ($):	
Payroll	4,411.92
Power	360.78
Repairs and maintenance	600.44
Supplies	423.11
Chlorine	1,289.28
Miscellaneous	423.11
Total	7,424.26
Total cost per m.g.*	37.00
Total cost per capita *	1.73

* Includes Parke, Davis wastes.

dried on the beds, all being used in liquid form as a soil conditioner.

A summary of operating data for the year is presented in Table I.

Editor's Note: This neat and complete report was prepared by the superintendent and only employee of a primary sewage treatment plant serving a population of 4,300. The report highlights the year's operation and furnishes complete operating data, including appropriate graphs. Sampling and analyses are on a Mon.-Wed.-Fri. schedule.

BALL-TYPE SEWER CLEANER *

A new and improved sewer cleaning device has been utilized by sewer maintenance personnel to flush sediment from pipe lengths between manholes. It is a hollow neoprene ball provided with diagonal ribs along the periphery. Use of the ball is simple and does not require extensive equipment.

To clean sewer lines, the ball is tied to a rope and air-inflated to fit snugly inside the pipe. The ball is then inserted into the line at a manhole producing a movable dam in the pipe. As the sewage backs up, the ball is allowed to move slowly downstream, while being controlled by the rope. When the head of water exceeds the air pressure in the ball, a jet of water is released under the ball (Figure 1), sweeping sediment ahead. At the same time the ribs on the surface of the ball scrape slime from the pipe wall. Only when there is a complete stoppage is it necessary to use sewer rods or other tools to open the line. The transported sediment is removed at the downstream manhole.

Neoprene is used for the ball because it is sufficiently tough to withstand the severe mechanical abrasion encountered. Resistance to the greases and chemicals normally present in sewer lines is an inherent characteristic of neoprene.

One city reports that at least 75 per cent of the sewer system is "balled" each year. Daily runs of 1 to 3 miles are not unusual. Approximately 855 miles of sewer have been cleaned at a cost of $90 to $95 per mile. This systematic balling was reported to cost less than a program designed around inspection teams.

* Extracted from *Neoprene Notebook*, Dec. 1954.

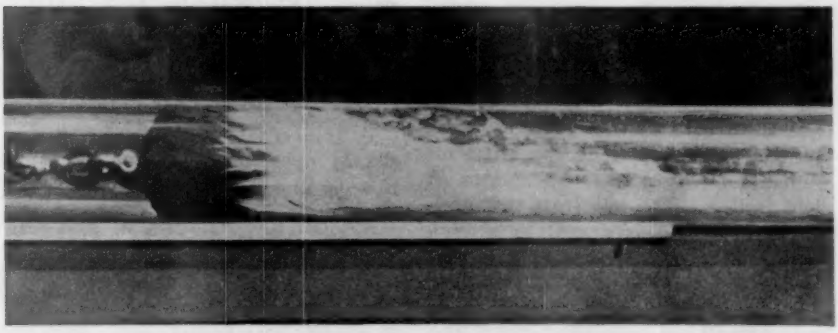

FIGURE 1.—Demonstration in transparent plastic pipe shows water sweeping past inflated neoprene sewer ball.

TIPS AND QUIPS

Shorter Hours—More Sewage *

Employees on all levels, white collar and blue collar, are talking about a 35-, 32- and even a 30-hr. work week. A reflection on the history of the labor movement will reveal that shorter hours can be expected in the foreseeable future. No one can predict precisely what the effect will be on the sewerage facilities of the communities. The shorter work week will probably intensify the movement to the suburbs and more residential developments will bloom, with critical demands on community services, particularly for water and sewers. The effect on sewerage will probably be confined to construction of new sewer lines and additional or enlarged treatment facilities. Problems of sanitating residential developments will tax the resources of engineer and financier. Spot problems will crop up in many places which will find themselves growing beyond expectation.

Then there is the increase in leisure time resulting in a virtual stampede to the open road and the recreation areas of the nation. With the increased use of recreational areas comes a louder voice for cleaning up the waterways. Even supposedly adequate treatment facilities will need re-evaluating as streams are up-classified for recreational use.

New Products for Spring Painting

Slip-Retardant Floor Paint

A slip-retardant floor and deck paint has been introduced by the Du Pont Finishes Division after 15 months of field testing. The relatively soft anti-slip agent is incorporated in a high quality non-metallic enamel and may be applied readily with a brush or spray gun. This anti-slip paint has been reported to be effective where oil, grease and water cause slippery surfaces. Colors available are light gray and maroon.

Zinc Protective Paint

Electrochemical protection of iron and steel similar to the galvanizing process is claimed for a recently introduced zinc-rich paint. The new paint is pigmented 100 per cent with zinc dust and contains selected plasticized polystyrene and chlorinated rubber as the vehicle. Zinc-rich paints have been in commercial use in England for several years and reportedly provide effective protection on new or rusty iron and steel surfaces.

Additional information may be obtained from the New Jersey Zinc Co., 160 Front St., New York 7, N. Y.

Scuff-Resistant Coating

A new plastic coating introduced by American Metaseal Corp., West New York, N. J., reportedly provides permanent scuff-resistance and porcelain-like beauty when applied to concrete surfaces of all kinds. The coating consists entirely of polyester plastic with added color pigments; there are no solvents to evaporate. It is claimed that the coating resists abrasion that is ordinarily destructive of chlorinated rubber and alkyd paints. Floors, walls, tank interiors and other surfaces can be given a smooth, glossy hard finish.

Bituminous Alkyd-Base Paint

A "one coat" rust and corrosion resistant paint has been announced by Speco, Inc., 7308 Associate Ave., Cleveland 9, Ohio. Combining a "heavy" bituminous alkyd base with a special penetrating vehicle, the paint is reputed to cut through moisture to the surface metal. It is especially recommended for application where conditions make it virtually im-

* Based on an editorial, *Public Works*, 87, 2, 7 (1956).

possible to thoroughly dry a metal surface. Coating is shiny black and elastic.

Multiple-Coat Paint System

A new intermediate primer reportedly insures a positive bond for finish coats of corrosion-resistant vinyl-resin paints. Vinyl-base coatings, while highly resistant to acids, alkalis and other chemicals, are notable for poor adhesion, particularly when the surface covered is chemically at variance with the vinyl resins in the paint. For metal and concrete surfaces an etch-action zinc-chromate wash primer is recommended. The intermediate primer is then used and the finish coat can be a vinyl-resin enamel.

A folder describing the ACANAL multiple-coat system is currently available from The Garland Co., Cleveland 5, Ohio.

Heat—A New Pollutant

Sewage disposal men, long familiar with the setting, moved over at the pollution conference table to make room for steam power officials at a recent meeting in Lansing, Mich.

Fish mortality in the Grand River below Lansing was traced to organic waste loading aggravated by a 10° F. temperature rise from power turbine cooling. Dissolved oxygen of the river was believed adequate to handle Lansing's sewage plant effluent but the dissolved oxygen decreased substantially in passing through the generating turbines. The steam power plant was using the entire river flow, up to 400 c.f.s. on days when severe oxygen depletion occurred.

Though serious in itself, the situation heralds greater trouble to come as power needs rise. Much lower flows than those of summer, 1955, are to be expected. The low 30-day period in the summer of 1936 averaged only 56.6 c.f.s.

Re-use of the water through cooling towers is indicated as necessary to keep the essential D.O. content up to the requisite minimum standard.

Ohio Sewage Treatment Plant Construction

According to the report of the Ohio Water Pollution Control Board, municipal sewage treatment projects under construction in Ohio during 1955 will total more than 100 million dollars when completed. More than 80 per cent of this sum is being invested in new or enlarged treatment facilities by the six largest cities in the state—Akron, Cleveland, Cincinnati, Columbus, Dayton and Toledo.

One-Coat Aluminum Paint

An aluminum anti-rust paint reputed to provide a brighter finish while eliminating the possibility of fading or "darkening" should find many uses on sewage treatment plant equipment. Pigmented aluminum is mixed with a colorless base vehicle. This makes a paint especially well adapted for roller application on wire fences where difficulty has been experienced in securing uniform paint coverage.

Known as Rust-Cure XX Aluminum, the new paint is suited for both indoor and outdoor use with a minimum of surface preparation. Additional information can be obtained from the Monroe Co., Inc., 10703 Quebec Ave., Cleveland 6, Ohio.

Jewels

A nationally known sanitary engineer is reported to have defined sewage as, "A glistening diamond transmuted by service to an opalescent pearl." The water works take the diamonds in the rough and the sewage works cleans up the pearls.

News and Notes

Of Persons and Activities in the Field of Hydrowastes

Professor Theodore Jaffe has recently headed up the sanitary engineering work, both academic and research, at Alabama Polytechnic Institute. Jaffe formerly was an Associate Professor of Sanitary Science at the University of Florida.

Florida's water resources are being studied by **Dr. David B. Smith**, on leave from the University of Florida, who has been appointed Director of the Florida Water Resources Study Commission, created by the 1955 Florida state legislature.

Professor Robert E. Stiemke, Director of the Civil Engineering School at Georgia Tech, has recently assumed his duties as President of the Georgia Engineering Society.

As part of the University of North Carolina's cooperative program in sanitary engineering education, **Dr. Marvin Granstrom** is at present working in Peru.

John C. Bumstead, former Consulting Engineer in Cincinnati, Ohio, has joined the staff of the Bureau of Sewage Disposal as Assistant Sewage Disposal Engineer for the city of Cincinnati. In this work, he will assist **Art Caster** in the increased administration work of the Cincinnati Sewage disposal program.

L. E. Ordelhiede, former Chief Engineer of the Missouri Division of Health, resigned his position as Executive Director of the Metropolitan St. Louis Sewer District and is now associated with the consulting engineering firm of Haskins, Riddle, and Sharp in Kansas City. **William Q. Kehr** succeeded to the position of Executive Director of the District.

Edmund J. Laubusch has accepted a position with the staff of the Chlorine Institute, Inc., New York. Since 1951 he has been a sanitary engineer reserve officer on active duty with the Public Health Service at stations in New York City, Cincinnati, Ohio and Washington, D. C.

Dr. Raymond W. Hess, Coordinator of Pollution Research, National Aniline Division, Allied Chemical and Dye Corp., Buffalo, N. Y., has been awarded the 1956 Jacob F. Schoellkopf medal of the Western New York Section of the American Chemical Society. The medal is being presented for Dr. Hess' outstanding contributions to the solution of the chemical, social and economical problems associated with the control of pollution. Active in many phases of his profession, Dr. Hess is chairman of the Industrial Wastes Committee of the Federation.

Federation Director-at-large, **Ray E. Lawrence** of Black and Veatch, was a member of the group headed by Kansas City Mayor H. Roe Bartle which made a 24-day goodwill tour of South American countries.

Automatic Control Co., St. Paul, Minn., has broken ground for its third and largest addition in six years. Manufactured is the Autocon line, precision liquid level and pressure control systems for water and waste treatment facilities.

Russell Stover Smith (58), died April 11 at his home in Mariemont, Ohio. Mr. Smith, a graduate of Harvard and M.I.T., served with the Public Health Service at Cincinnati since 1934. He was a member of the Quarter Century Operators' Club, having been a sanitary engineer for the Sanitary District of Chicago.

Dr. W. B. Hart has been named Director, Industrial Wastes Engineering Division, Pantech, Inc., Folcroft, Pa. For more than 30 years he directed the activities of the Waste Control Division, Atlantic Refining Co.

Willis L. Ogden (33), Vice-President of the Lakeside Engineering Corp., died suddenly, March 26, at Janesville, Wis. He was a graduate of the University of Illinois and Harvard University.

B–I–F Industries announces the appointment of six district engineers in a continuing program to develop complete and specialized services for its customers. Among the appointees are Federation members **L. H. Chamberlain** (Calif.), **E. F. Morey, Jr.** (Tex.), **C. K. Perkins** (N. Y.) and **G. E. Riepe** (Cen. St.).

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A Bulletin 22S61, explaining complete details of DIFFUSAIR equipment is available upon request. Write for your copy today!

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Proceedings of Member Associations

IOWA SEWAGE WORKS ASSOCIATION

The 1955 Annual Meeting of the Iowa Sewage Works Association was held at the Hotel Wahkonsa, Fort Dodge, Iowa, September 7–9, 1955. The program featured two panel discussions. One covered the topic "Trickling Filters, A to Z," and the other was devoted to various aspects of sludge digestion.

At the business meeting, the name of the Association was unanimously changed to "Iowa Sewage and Industrial Wastes Association" in keeping with the increased scope of membership interests. Officers elected were:

President: V. Garwood, Grinnell.
Vice-President: K. Hirlinger, Ottumwa.
Secretary-Treasurer: L. F. Skorczeski, Marshalltown.

L. F. SKORCZESKI,
Secretary-Treasurer

GEORGIA WATER AND SEWAGE ASSOCIATION

The 1955 Annual Meeting of the Georgia Water and Sewage Association was held at the Georgia Institute of Technology, Atlanta, Ga., September 21–23, 1955, in conjunction with the Annual Georgia Water and Sewage School.

Officers were elected as follows:

President: W. W. Kiser, Rome.
Vice-President: F. L. Futral, Newman.
Secretary-Treasurer: A. T. Storey, Atlanta.

A. T. STOREY,
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GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variation in velocity. *Design data in Technical Supplement CR.*

GRIT SETTLERS—with conveyor, elevator, and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249B.*

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Bulletin 260B.*

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AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265A.*

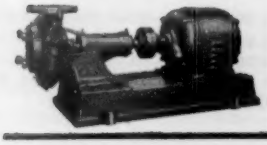
JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Bulletin 265A.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Design data in Technical Supplement RD.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Design data in Technical Supplement PF.*

Send for informative bulletins listed above.

Inquiries on new installations or improvements of existing plants will receive prompt attention.



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(Continued through page 213a)

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